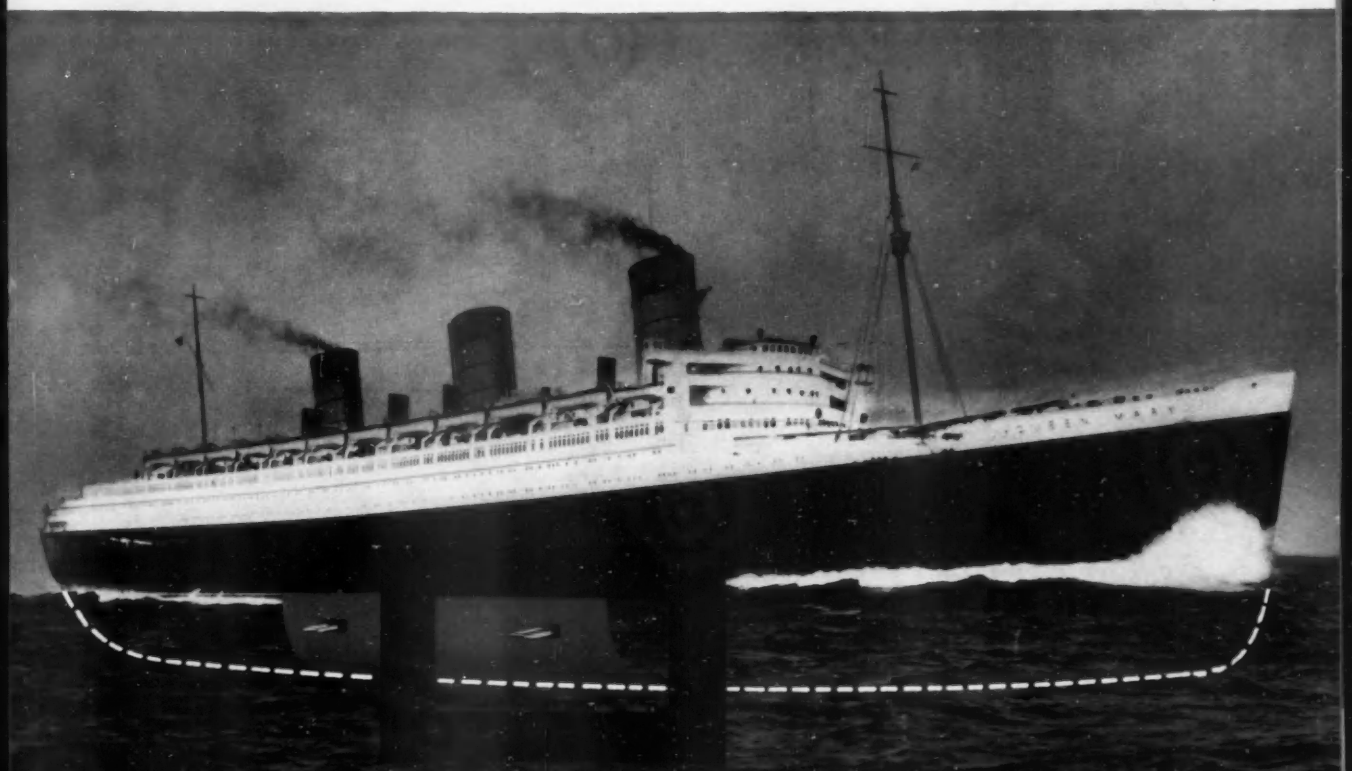
Control ENGINEERING

INSTRUMENTATION AND CONTROL SYSTEMS

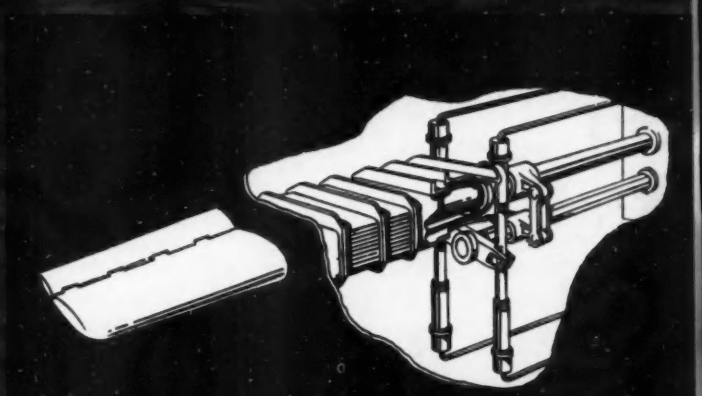
A McGraw-Hill Publication

75 Cents

MARCH 1959



CONTROL FINS STABILIZE THE Queen Mary



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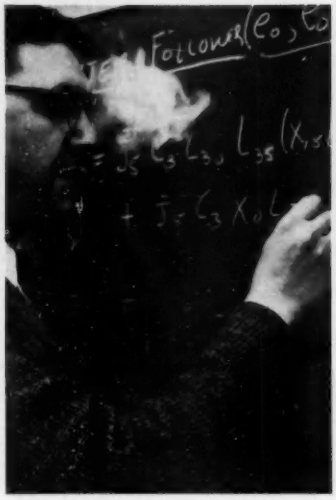
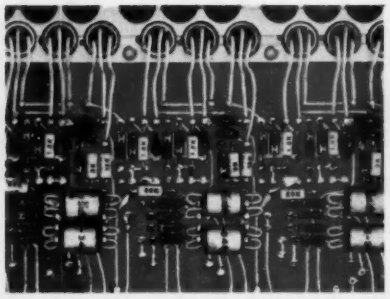
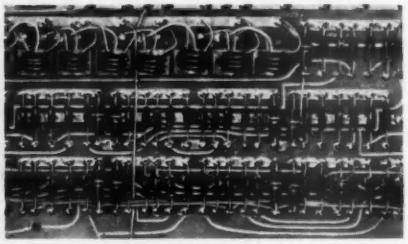
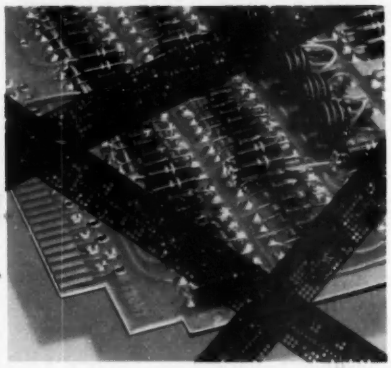






what goes into a computer system.....



... more than experienced engineering, more than parts, plans and programs. At Librascope, it is the ability to integrate components and brain-power into workable computer systems for the accurate translation of data.

Librascope engineers attain optimum system accuracy by weighing problems in terms of inputs available and outputs required to provide reliable answers.

This process, from concept to reality, has unlimited room for expression at Librascope where facilities including field test and simulation laboratories cover hundreds of thousands of square feet... where research—development of electronic, electro-mechanical, magnetic and optical computing techniques is a continuing, progressive program.

What goes into a Librascope computer system represents the best experience of two decades. For full details on how Librascope can anticipate and solve your computer and control problems, write...

For information on career opportunities at Librascope, write Glen Seltzer, Employment Manager.

LI 9-2

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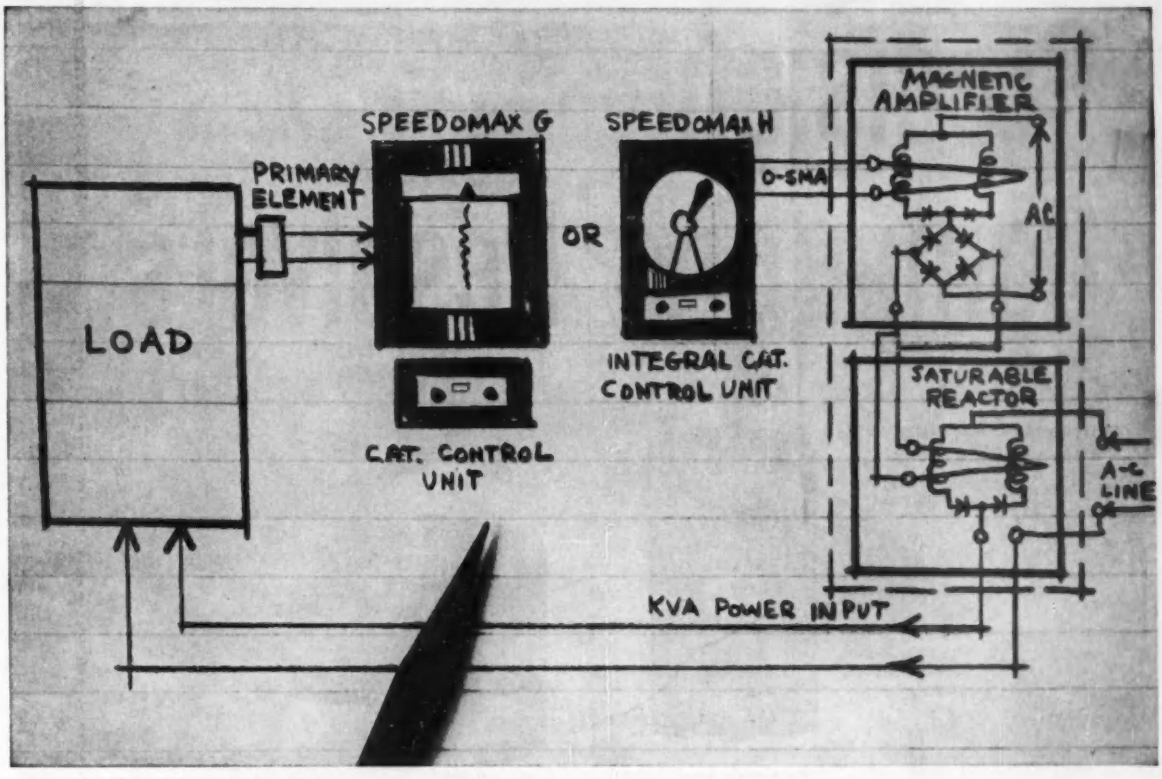
CIRCLE 1 ON READER-SERVICE CARD



Now...Stepless control of Electric Heat Input with L&N's (new) C.A.T. control system

If your process uses electric heating equipment and your product is off-temperature due to cycling of heating elements at high temperatures . . . if excessive downtime and expensive replacement of worn-out contacts cut down production time . . . it'll pay you to learn about L&N's new Current-Adjusting Type control for continuous, efficient power output in saturable core reactor systems.

Already in use on applications like crystal growing and strip annealing, this control permits stepless regulation of power output over the *entire operating range of saturable core reactors.* Its rapid speed of response matches rapid changes in product temperature. The wide range of adjustment of proportional, reset and rate actions facilitates tuning the system to your process, product and production.

C.A.T. control is a complete system consisting of (1) a primary element, (2) Speedomax® recorder, (3) C.A.T. control unit, and (4) a magnetic amplifier and saturable core reactor.

Heart of the system is the C.A.T. control unit. Any temperature change, detected by the primary element and measured by the recorder, is fed to the control unit. Continuous d-c output of the unit over 0 to 5 ma range drives a magnetic amplifier. The d-c output of the magnetic amplifier is fed to the control windings of a saturable core reactor for continuous regulation of power input to the process.

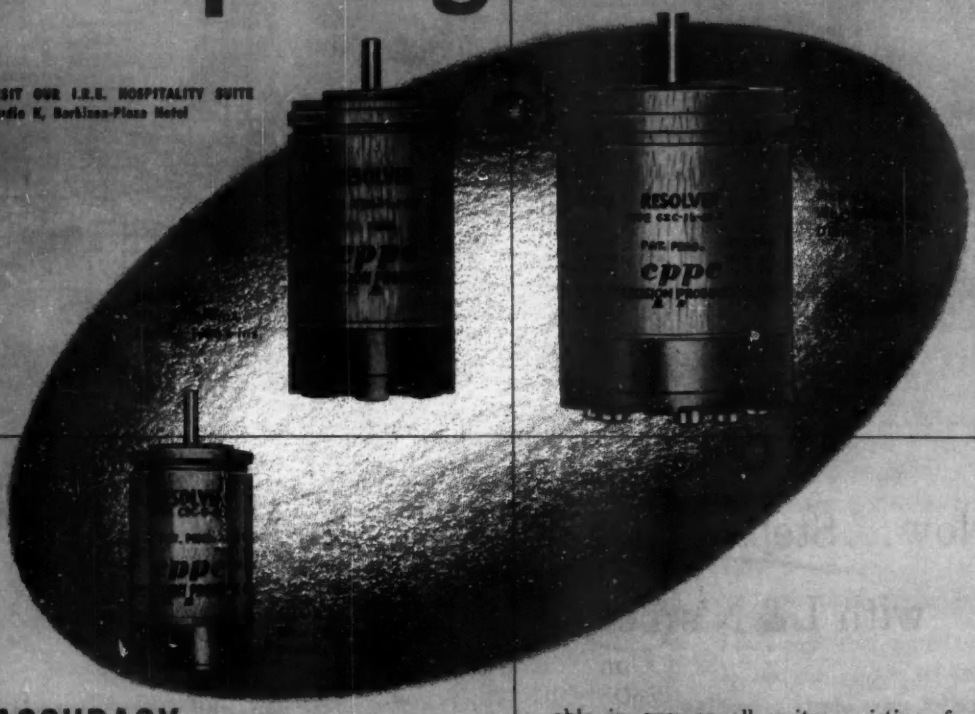
If you're modernizing your present electric process equipment or installing new—make use of our wide experience in providing temperature control systems for thousands of applications. For more information, contact your nearest L&N sales office, or write us at 4918 Stenton Ave., Philadelphia 44, Penna. Ask for Data Sheet ND 46-33(107).

LEEDS Instruments LN NORTHRUP Automatic Controls • Furnaces

CIRCLE 4 ON READER-SERVICE CARD

Precision Computing Resolvers

VISIT OUR I.R.E. HOSPITALITY SUITE
Studio K, Barbizon-Plaza Hotel



ACCURACY

Highest accuracy in rotating components is a CPPC fundamental. Our Precision Computing Resolvers are no exception. Without compensation, a recent production run of resolvers showed functional errors of .06% *or less.* Perpendicularity of axes was ±3′ in 360°. Due to extreme symmetry of rotor and stator, nulls are excellent in these resolvers. Low phase shifts are also a feature.

VERSATILITY

CPPC Precision Computing Resolvers can be had with any of the following features: corrosion resistant construction, stainless steel or aluminum housing. Units to resist temperatures up to 450° F. The following compensation is available in any or all units: resistive, feedback winding, thermistor. Types available for transistor circuitry. Pin or screw terminals or lead wires. BuOrd type shafts and BuOrd MK 4 Mod 0 brush block obtainable.

PRICE AND DELIVERY

We ask you to review what you are paying for precision computing resolvers. In the past CPPC has been able to lower traditional prices of rotary components.

We are already tooled for many types of these resolvers and can make quick delivery in quantity or short run. Whenever you need *any* rotary component, think of CPPC.

Call or write Sales Department, HIlltop 9-1200 (Suburban Philadelphia) or our Representatives.

ENGINEERS—For a career in rotary components and computers, write David D. Brown, Personnel Director, Dept. N3

cppc

CLIFTON PRECISION PRODUCTS CO., INC.

CLIFTON HEIGHTS, PENNSYLVANIA

Control ENGINEERING

MARCH 1959
VOL. 6 NO. 3

Published for engineers and technical management men who are responsible for the design, application, and test of instrumentation and automatic control systems

Continued on next page

Control ENGINEERING

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Postmaster: Please send form 3579 to Control Engineering, 330 W. 42nd St., New York 36, N. Y.

Announcing CMC's
New Model 400C

The most versatile DIGITAL PRINTER ever made!

MODEL 400C

ALL NEW, the CMC Model 400C is a reliable, economical instrument for permanently recording digital data from counting, timing, frequency measuring, and data handling systems.

EIGHT OPTIONS OFFERED

Optional features which broaden the area of application for the CMC digital printer:

• 10 line output for operating punches and electric typewriters • analog output for driving strip chart and other pen type recorders • built-in inline readout for visual monitoring at a distance • accumulator for totalizing • code converter to accept any digital code, Model 400C is compatible with any make of counting equipment • transistorized drive which accepts low voltage input • an add-subtract solenoid which prints plus and minus numbers • print-line identification for coding printout.

New Standard Features

Standard features designed to improve reliability and flexibility include elimination of stepping switches, 4 line per second printout, parallel entry, and rugged unitized construction.

Key Specifications

Print-out capacity 6 digits standard, up to 12 on special order • **Accuracy** determined by basic counting instrument • **Display time** 0.2 seconds minimum, maximum controlled by the counter • **Weight** 64 lbs. • **Price** $950. Add $10 for rack mount.

See CMC at the IRE Show, New York, March 1959. Booth No. 1620

CMC engineering representatives are located in principal cities. For more information on this versatile instrument, phone your nearby representative or write directly to Dept. 083.

CMC 9 8 7 6 5 4 3 2 1 0

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CIRCLE 6 ON READER-SERVICE CARD

SHOPTALK

Lunik drives us Loony

We coudn't tell you this story last month, because *Shoptalk* was already off the press by the time the plot started to unfold. Here was the picture: the February issue was closed, most of it was either already printed or on the press, and the editors could relax momentarily before starting the push for March, when along came a story on the Russian Lunik from the Bonn News Bureau that contained more detail than we'd ever been able to get on the guidance and control system of any U. S. missile. The question: could we still get it in February? A phone call told us that the last form in the magazine and the front cover hadn't gone on the press yet. The relaxation period ended. A quick rewrite, a layout, and drawings and engravings made overnight gave News Editor Lew Young a package to carry to the printer the next morning. The result: a CtE exclusive, "How the Russians Put Lunik into Orbit", on page 168 of the February issue.

Conference program finalized

Many a tasty morsel will be awaiting the control engineers who attend the Purdue-CtE Conference on Industrial Control System Components, to be held at Purdue on May 4 and 5. The program has been firmed up, and all the information on papers and authors is given on page 31.

Control engineer designs and tests

Abraham M. Fuchs (author of the series on control system test equipment, starting on page 116) has designed and tested enough control systems to know what he's talking about. After receiving a BS in EE from CCNY and a MS in EE at MIT, Abe designed control systems at the MIT DACL, Bendix Aviation Corp., Westinghouse Air Arm Div., and CDC Control Services, Inc., then started his own business (Boonshaft & Fuchs, Inc.) in November 1958. Abe's also done his share of extracurricular work in the control field, writing articles, chairing the program subcommittee of the AIEE Feedback Control Systems Committee, and teaching servomechanisms design. On top of all this, he spends part of his spare time trying to understand the individual's motivation as explained by Freudian theories.

A look ahead

Here's a sampling from the April issue: a three-part symposium on hot hydraulic and pneumatic control systems; details of the parametron—a new Japanese computing component; how to handle the effect of piping on valve performance; transistor-thyratron control of two-phase motors.

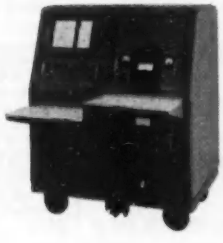
CEC's design capabilities and facilities for developing and producing complete missile ground support equipment is a matter of record. Typical of CEC's ground support equipment are static and dynamic checkout units for fuel systems . . . propellant utilization exerciser systems...and electronic systems for telemetry, inertial guidance, and control checkout. For full information, send for CEC Bulletin 3017-X3.

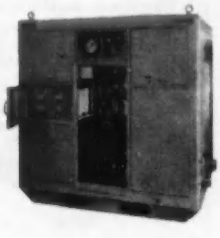
Consolidated Systems **CEC**

CONSOLIDATED ELECTRODYNAMICS *300 N. Sierra Madre Villa, Pasadena, Calif.*

FOR EMPLOYMENT OPPORTUNITIES WITH THIS PROGRESSIVE COMPANY, WRITE DIRECTOR OF PERSONNEL

Propellant Utilization System Exerciser sequentially generates precise pressures for the fuel and oxidizer channels at 25 preselected points on a scale from zero to maximum, making possible precise checkout.

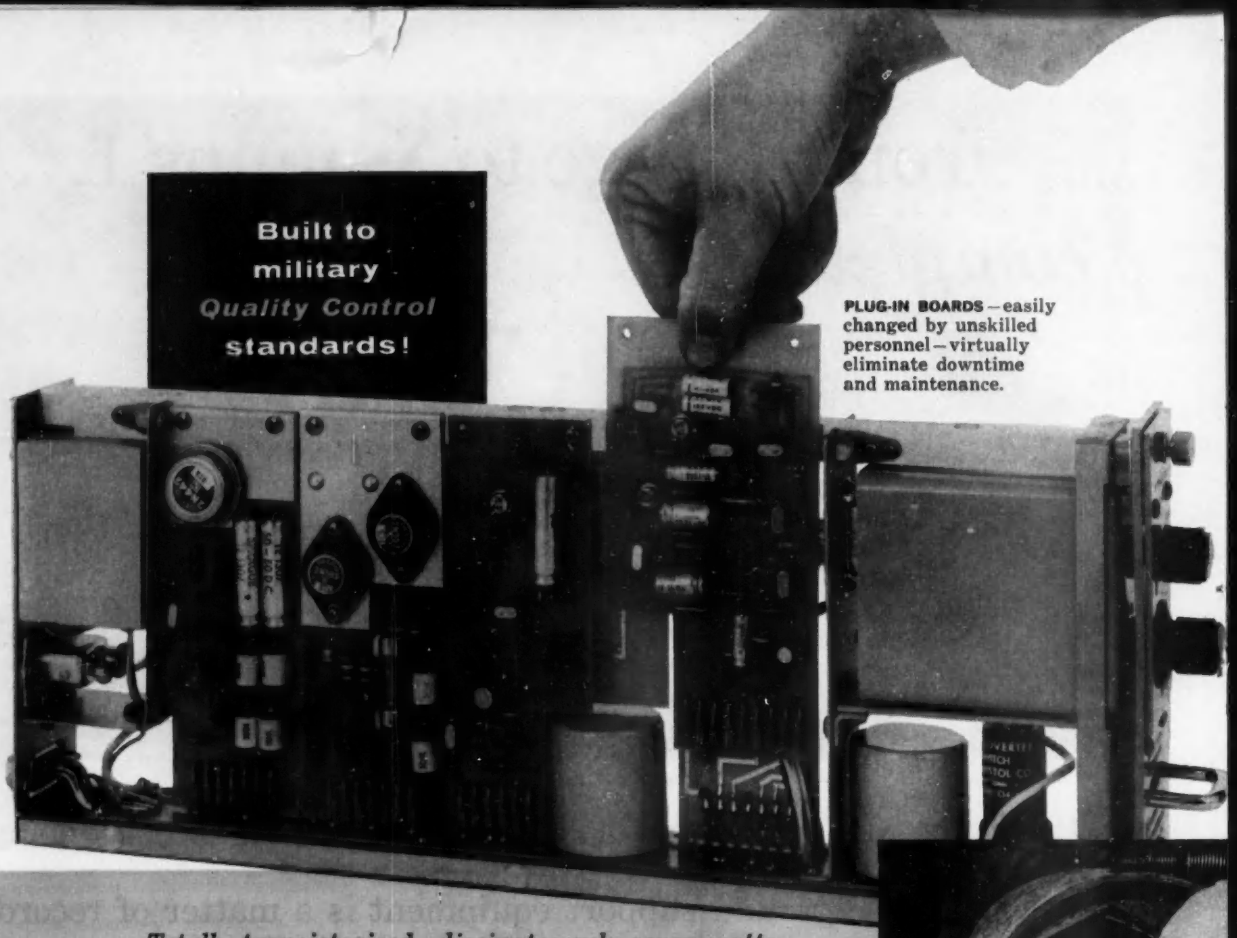




Pneumatic Checkout System is essentially a go, no-go device that automatically pressurizes and tests missile pneumatic systems during storage and pre-countdown periods. Sensing units detect any malfunction, transmit signals to automatic comparator.

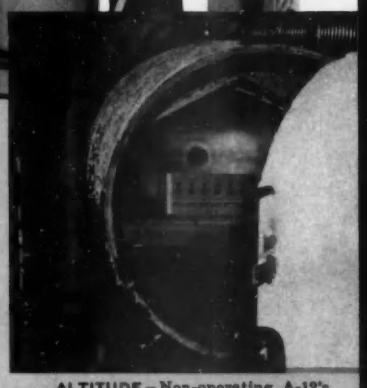
CIRCLE 8 ON READER-SERVICE CARD

Built to military *Quality Control* standards!



PLUG-IN BOARDS—easily changed by unskilled personnel—virtually eliminate downtime and maintenance.

Totally transistorized—dissipates only seven watts.
Drift less than 2 microvolts per 200 hours.
Single ended or differential input.
19" panel accommodates eight instruments.
DC to 50,000 cps.
Noise less than 10 microvolts wideband.
Operates to specifications from 0 to 50°C.
Self-contained power supply—operates on any line frequency from 50-400 cps.
Mil-type chopper gives unmatched reliability for the life of the instrument.



ALTITUDE—Non-operating A-12's were subjected to 1.6 psi (50,000') for one hour, and then operated at 6,000' and at sea level pressures.

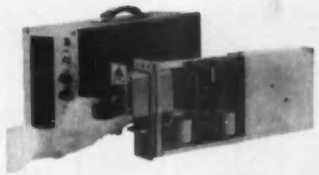
SPECIFICATION SUMMARY – MODEL A-12

	Single Ended Input	Differential Input
Gain:	Fixed gain set to any value from 10 to 1000 inclusive by front panel plug-in units. Gain switching plug-in attenuator available with gains of 0, 10, 20, 50, 100, 200, 500 and 1000. Adjustable upward 2½ to 1 or more from setting with potentiometer.	Fixed gain set to any value from 10 to 1000 inclusive by front panel plug-in units. Gain switching plug-in attenuator available with gains of 0, 10, 20, 50, 100, 200, 500 and 1000. Adjustable upward 2½ to 1 or more from setting with potentiometer.
Input Impedance:	100 megohms shunted by 0.001 mfd (typical).	10,000 ohms.
Source Impedance:	5K maximum.	
Drift:	Less than 2 microvolts in 200 hours at constant ambient temperature. Less than 0.4 microvolt per degree centigrade.	Less than 4 microvolts in 200 hours at constant ambient temperature. Less than 0.8 microvolt per degree centigrade.
Ambient Temperature:	0° to 50°C.	0° to 50°C.
Noise (Referred to input):	0-3 cps 5 microvolts peak to peak. 0-750 cps 5 microvolts rms. 0-50 kc 10 microvolts rms.	0-3 cps 10 microvolts peak to peak. 0-750 cps 7 microvolts rms. 0-50 kc 14 microvolts rms.
Frequency Response:	±3db to 50 kc (typical); ±1.0% to 2 kc.	±3db to 50 kc (typical); ±1.0% to 2 kc.
Output Capability:	±10 volts at ±100 ma DC or peak AC to 10 kc.	±10 volts at ±100 ma DC or peak AC to 10 kc.
Common Mode Rejection:		100db at DC; 72db at 60 cps for common mode voltage up to 50 volts DC or peak AC.

Only Electro Instruments DC Amplifiers meet rugged military environmental tests!

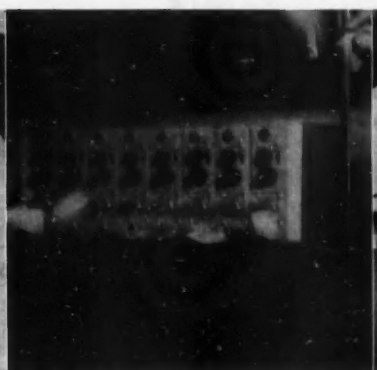
Totally-transistorized Model A-12's picked for ICBM Ground Support Equipment

The photographs below were taken while eight Model A-12's were undergoing environmental qualification tests by independent MIL-approved laboratories.

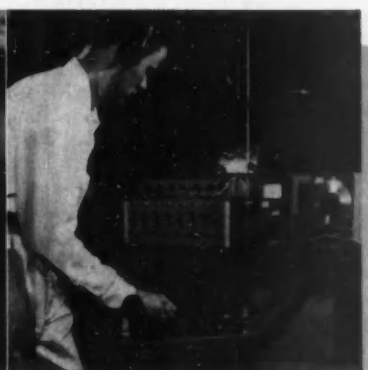


PLUG-IN ATTENUATORS provide a choice of differential, single ended, or operational inputs for maximum operator convenience, flexibility and economy. Special variations, gain settings, etc., can be tailored to *your* system at no extra cost.

TEMPERATURE—The A-12's were operated at 50°C. ±2° for 12 hours and at 0°C. for 12 hours, and after storage at 70°C. and −40°C. for 24 hours.



SHOCK—The A-12's were subjected to 4" pivot drops and 1" free drops on all practicable faces for a total of five drops on each face.



ELECTRO INTERFERENCE—All tests conformed to RADC Exhibit 2313A.

The A-12 is certified as incorporating no fungus nutrient material!

Design and construction techniques of the Model A-12 Amplifier are fully *two years ahead of the field!* Totally transistorized circuits give the A-12 unmatched reliability and performance, and minimize heat dissipation problems inherent in vacuum tube instruments. Plug-in etched circuit boards and modular internal construction make servicing and maintenance checks easy—the amplifier can be disassembled and reassembled in less than 10 minutes. These advanced features enabled the Model A-12 to meet stiff military environmental qualification tests and resulted in their being selected for use in the ground support equipment of the nation's most advanced ICBM program.

Why not ask your E-I representative for the full story today?

SMALLEST PACKAGE EVER!
Eight Model A-12's can be mounted in standard 19" panel.

Electro Instruments, Inc.

3540 AERO COURT
SAN DIEGO 11, CALIFORNIA

CIRCLE 9 ON READER-SERVICE CARD

FEEDBACK

Filed for future reference

To the Editor—

The article, "Graphical Analysis of Hydraulic Servos", which appeared in your April '58 issue, describes the sort of work we've been doing recently. We recently built a test machine which extensively involved hydraulic servos. As soon as someone says there is an easy way to analyze something, I'm always interested.

I am saving this article as it will help us in the future in the design process of a new control system. It will help in the selection of components. It is a general, theoretical design article—a "how-to" article with flexibility of use.

Donald J. Fritch
Electronics Engineer
Lessells & Associates Inc.
Boston, Mass.

One for the record

To the Editor—

Your Dec. '58 issue is an outstanding publication and is a real accomplishment. Readers of that issue might like to know that the TAG chart you showed (page 71) is an adaptation of my development of the mechanization profile technique of comparing the degree of mechanization and automatic action in any type of physical system. The concept is based upon the identification of 17 levels of mechanization and subsequent plotting of the level of each activity. The technique and results in some eight or ten plants are given in detail in the book, *Automation and Management*, published by the Div. of Research, Harvard Business School, Boston 63, Mass.

James R. Bright
Harvard University
Boston, Mass.

Wanted—traffic control literature

To the Editor—

I am inquiring about applications of "modern" computer and control systems to vehicular traffic problems. My concern is to locate pertinent articles or books about or referring to such systems—more importantly, the mode of thought or "philosophy of approach" to solutions of problems of that sort.

Erwin Krieger
Cincinnati, Ohio

Operations Research, the journal of the Operations Research Society of America, is a good source of information on philosophy and mathematical studies of traffic control. General Precision Laboratories and IBM are among the business organizations that have studied the problem with computers (CtE, Jan. '59, p. 22). Ed.

At 67 he wants to retread

To the Editor—

Very impressed with your neat assembling of Control Engineering, I wish to get a copy of "Manual of Digital Techniques" and one of the special December '58 issue on industrial modernization. Please start my subscription right now.

I am 67, have just retired from 18 years' work as a control chemist, am returning to Ohio from Florida, and wish to take a course in engineering physics. I have an AB degree in inorganic chemistry and an AM degree in biochemistry. My work has included two years of research on vitamin C, for which I was made a member of the Louis Pasteur Society.

Now please help me to select the best courses in engineering work, including physics, math, and other courses that best fit into control engineering work, to bring me up to date.

Lewis M. McCormick
Athens, Ga.

And we thought that the control engineering field was a young man's game! Ponce de Leon and McCormick searched Florida for the fountain of youth. The Spaniard never found it, but McCormick may, in the stimulus of the control engineering field.

In his part of the country, he might investigate Case Institute, Ohio State, and Purdue. Ed.

Wanted—100 lines per min printer

To the Editor—

To provide a continuous readable record of what is happening in shift production, we need a printer that will operate on simultaneous signals from a factory data readout system that feeds data to an IBM 523 card punch. We have looked without success for several months.

The readout is "broadside" at the rate of 100 lines per minute, paced by the 523. The complete output of 72 columns (containing two alphabetics which could be dropped) could be reduced to 27 numeric characters per line, the really vital information.

Because readout occurs only when job conditions change and at the end of each shift, the printer's usage

FEEDBACK

will be low and therefore the typical higher-speed printers used with a computer cannot be economically justified.

If one of your readers knows of a unit which fills the broad gap between a high-speed printer and an electric typewriter, I would very much appreciate hearing from him about it.

Harold F. Smith
Advanced Mfg. Development
Appliance & Television Receiver Div.
General Electric Co.
Louisville 1, Ky.

If there were a printer that fitted your need, it would probably be too expensive. Since you need printout only at the end of each shift use a buffer storage and an automatic typewriter. But let's see what other readers suggest. Ed.

Wanted—more detail

TO THE EDITOR—

We would like information on Case Histories 3 and 4, given by Donald W. Richmond of Monsanto Chemical Co. and John R. Donovan of the same company, in CONTROL ENGINEERING, the December '58 issue.

T. L. Douglas
Lever Brothers, Ltd.
Toronto, Canada

Contact the two authors through T. J. Williams, Monsanto Chemical Co., Lindbergh and Olive St. Rd., St. Louis 24, Mo. Ed.

This bouquet hides a thorn

TO THE EDITOR—

Thank you very much for the special report, "A Team Reports on Control Inside Russia" (November '58 issue). I think that you and the other members of the AACC team are to be complimented for an excellent job of reporting on your recent visit abroad. I know in my case all too frequently the ideas and impressions that I acquire on a visit such as yours never are spread nearly as widely as might be desired. Certainly, with the depth of talent that you had on this team, we here in America are very much in your debt for presenting this accurate and up-to-date picture of what is going on in the control field in Russia. The speed with which you got out this report is simply amazing.

I was also delighted to see that you had Professor Letov as your *Control Personality* of the month. This was

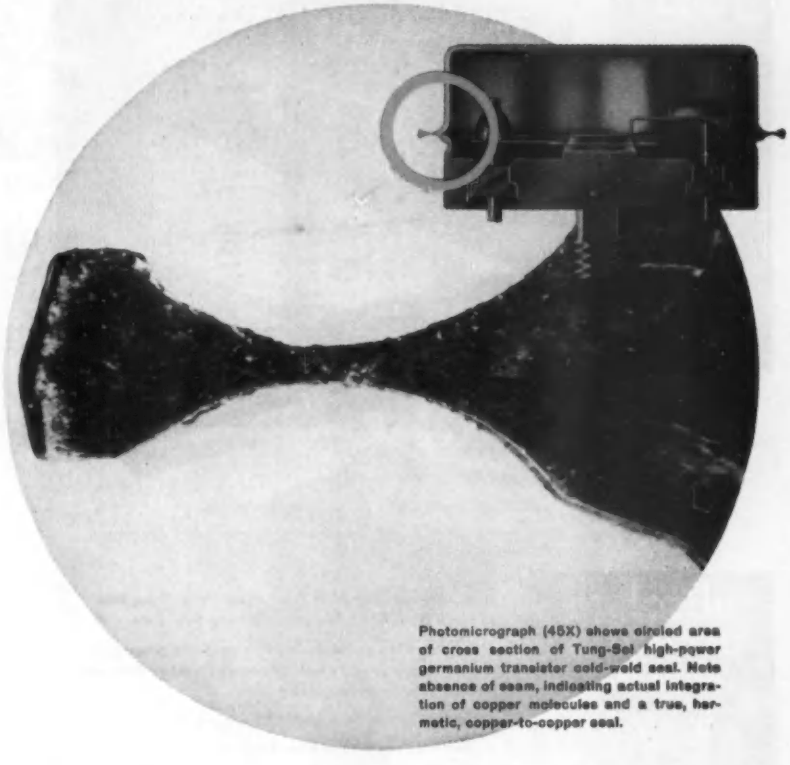
Tung-Sol moves ahead!

Now

High power transistors with new **cold-weld** seal

Improved cold-weld seal gives new Tung-Sol high-power transistors three-way quality boost

- True hermetic, copper-to-copper seal improves transistor thermal characteristics.
- Elimination of heat-damage, heat-caused moisture and "splash" increase reliability.
- Vacuum-tight, moisture-proof cold-weld seal lasts even through "breathing" over long life operation.



Photomicrograph (45X) shows circled area of cross section of Tung-Sol high-power germanium transistor cold-weld seal. Note absence of seam, indicating actual integration of copper molecules and a true, hermetic, copper-to-copper seal.

Once again Tung-Sol shows the way. Now, for the first time, Tung-Sol brings designers high-power germanium transistors with quality benefits of the advanced cold-weld seal.

The new Tung-Sol types feature a stud-mounted package and maximum collector current of 13 amps. Military environmental tests combine with the radioactive gas leak detection test to assure maximum reliability.

Technological advancements such as this keep Tung-Sol ahead of the field. For full data on the new high-power switching transistors . . . to meet any need with the latest in transistor design and efficiency, contact: Semiconductor Division, Tung-Sol Electric Inc., Newark 4, New Jersey.

TUNG-SOL®

AT THE IRE SHOW—BOOTHS 2833, 2835, 2837, 2839

CIRCLE 13 ON READER-SERVICE CARD

FEEDBACK

indeed fitting and appropriate and I am sure that the impression that you gave of the first vice-president of IFAC will serve to make him a more well-known personality to the many thousands of control engineers who read CONTROL ENGINEERING. As I looked through the article on Letov, I failed to note any mention of his being first vice-president of IFAC or that he is chairman of the National Committee of the Soviet Union on Automatic Control, which will be responsible for the First International Congress of Automatic Control to be held in Moscow in 1960. Although doubtless this will be brought to the attention of your readers as plans for the congress develop more fully, I hope that you will be able to identify Letov with the IFAC organization in the near future.

Harold Chestnut
Control Systems Engineer
General Electric Co.
Schenectady, N. Y.

Editorial space is tight; something always has to go. Professor Letov's present title, as well as his next one, will receive full recognition when he takes over from Mr. Chestnut as president of IFAC. Ed.

To perforate or not to perforate

TO THE EDITOR—

I do not agree with perforating the feature section. It tears out entirely *too* easily! Why not use a smaller perforation, if required, similar to the perforation used in *Business Week*? I for one, vote for smaller or *no* perforation, so that I can keep all issues intact.

George F. Rutter
Seattle, Wash.

TO THE EDITOR—

In *Shoptalk* of the January '59 issue, you ask for comments on perforations for the feature section. I am in favor of some such aid for all articles. But even in the January issue I found it necessary to use a knife to cut out an interesting article. You have taken a good first step.

Paul J. Blake
Clairton, Pa.

Oops. Our printer did not put the perforation bar in the folding machine before the big feature form was folded and trimmed. Our apologies.

Letters from librarians indicate they dislike perforations. Because we adopted perforations so that you could more easily remove articles for your own use, we ask you—should we continue to perforate or not? Ed.

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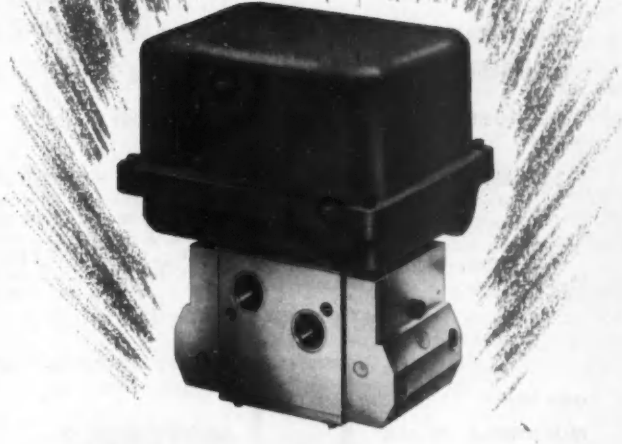

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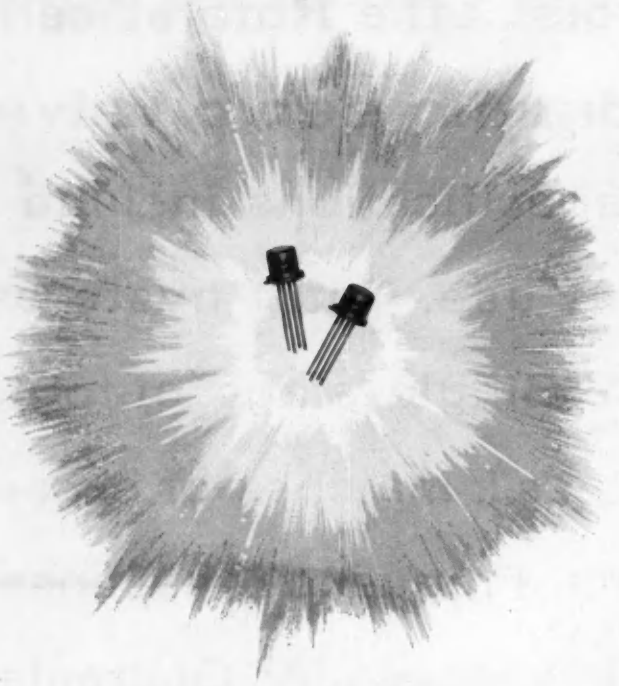

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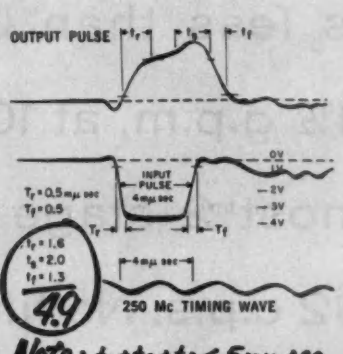
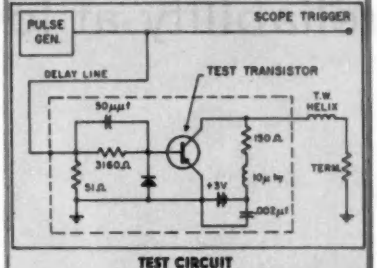


Note: $t_r + t_s + t_f < 5 m\mu sec$



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 CIRCLE 16 ON READER-SERVICE CARD

WITHOUT USING THE COMPUTER: problem

Thomas C. Wherry

boosts the process payoff

At Phillips Petroleum today, top management encourages the use of new, advanced techniques of process instrumentation and control—with one proviso: the new tool has to pay off economically. The man who's been proving the economic worth of such new devices for the Bartlesville oil company is an outdoors-loving Scotsman, Tom Wherry.

As manager of Phillips' newly-formed Instrumentation & Automation Branch (in the Process Development Dept.), Wherry is interested in more than economics. His job, as he sees it, is to "figure out better ways to measure and control, to develop a workable system, to convince operating people to try out the system in the plant, and then to justify it for use at other Phillips installations".

For such a job, Tom Wherry has almost an ideal background. At Kansas State University in 1938, he received both BSEE and a BSChE degrees. He joined Phillips after graduation and has been with the oil company ever since.

His first job was in the Production Dept. After a year, he transferred to the R&D Physics Div. for geophysical work. When World War II ended exploration, Wherry moved on to pilot plant and process design. It wasn't until 1947 that Tom got his first introduction to instrumentation application.

Transferred to the Instrument & Equipment Branch, Wherry found the oil industry, placed little emphasis on instrumentation. His experience with production and process design convinced him that his first task was to sell operating people on the benefits of advanced instrumentation. To do a real job, he found, requires a strong knowledge of both process and instrumentation—and the ability to spot control problems with economic payoff.

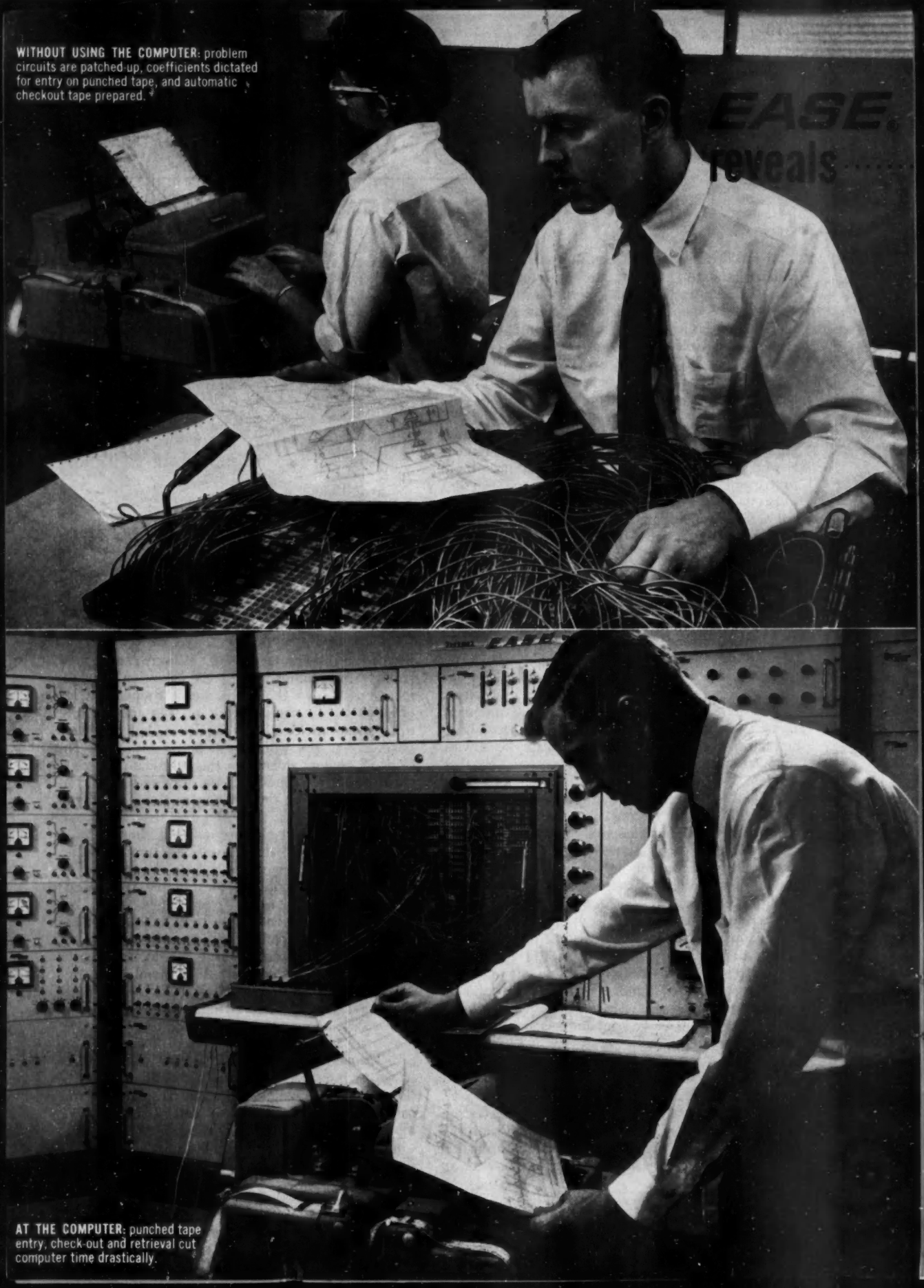
Pursuing new concepts aggressively has taken time and has taught Wherry patience, a trait he feels is an essential for a process control engineer. As a technical example, he points out that the span from successful operation of a new instrument in the laboratory to satisfactory operation in the plant can be a long, trying period. Back in 1947, to cite one case, Wherry started to improve negative-type infrared analyzers for plant use. It was six or eight years before the bugs were worked out and a large number of these devices were finally on-stream in Phillips' refineries.

Today the company recognizes the role instrumentation can play in the profit picture. Under Tom's guidance, the company has pushed successful in-plant application of infrared and ultraviolet analyzers, differential refractometers, and chromatography. But pushing out frontiers has proved to have some disadvantages, too. Wherry campaigned strongly for Phillips' widespread adoption of chromatography even though it meant dropping a lot of hard-gained original work on the uses of the mass spectrometer. The chromatograph, Wherry believes, has and will have a better future for analysis of product streams in the petroleum industry.

In further recognition of the importance of control, Phillips set up the Instrumentation & Automation Branch on Jan. 1, 1959. The new group will give Manager Tom Wherry a better shot at some of the problems of the future. For tomorrow, he feels the control engineer needs to define some of his newly coined concepts (for example, systems engineering, automation, and computing-control) because top management has to have these definitions to assure proper direction and emphasis.

Wherry looks to activities of ISA to help clarify these concepts. Long an active member in the society, Tom is now serving as technical vice-president, encouraging the presentation and publication of new developments.

Wherry also believes that more effort will have to be expended to design for reduced maintenance. A lack of trained maintenance people, he feels, may slow up the introduction of advanced concepts and hardware. For despite his sincere interests in promoting the new concepts, Wherry never forgets what he says is the prime job of process control: to improve the process payoff.



WITHOUT USING THE COMPUTER: problem circuits are patched-up, coefficients dictated for entry on punched tape, and automatic checkout tape prepared.

AT THE COMPUTER: punched tape entry, check-out and retrieval cut computer time drastically.

.....HOW TO SOLVE MORE ANALOG PROBLEMS IN LESS TIME

How Much Time Does a Computer Spend Computing?

As analog computing problems become more complex, more time is spent setting up and checking the electrical analog, and less time actually generating solutions. When we consider that actual computation sometimes occupies less than 1% of total computer time, it becomes evident that any method of speeding up or eliminating set-up and check-out tasks offers immense rewards —either by expanding problem-handling capacity or reducing the size and cost of an adequate installation. This month we wish to acquaint you with some of the time-saving techniques which have become practical with the introduction of digital control units.

A Device for Reducing "Non-Computational" Time

The EASE digital control unit, nicknamed the "DO/IT" system, is more formally known as the "digital output/input translator." Because we know it best and because we believe it excels in general utility, we will talk about ways of using the DO/IT. A number of the techniques are applicable to other digital control systems.

In case you are unfamiliar with the DO/IT, it is a mechanism for entering and retrieving information via typewriter and punched tape. Its essentials are a Flexowriter coupled to the computer through a battery of telephone-type relays. The relays actuate a digital-to-analog converter which, in turn, drives a servo-set potentiometer system. The DO/IT is capable of entering coefficient pot settings, commanding the computer to assume any operational state, and reading out values at any or all points in the problem-solving circuit. Although designed for EASE computers, the DO/IT will operate with other analog equipment.

Keeping this in mind, let us point out some of the techniques that have proved to be enormous time-savers at our Los Angeles Computation Center.

Eliminate Pot Set Error

The trick is to screen out errors before approaching the computer. A punched tape and typewritten record of pot addresses and desired coefficients is prepared in advance on a Flexowriter. This is checked and errors are corrected before entry. How about errors in the servo setting? These are more unlikely, but to insure that they do not occur undetected, the DO/IT prints out the actual setting after each command and conscientiously prints the setting in *red* if it deviates more than 20mv from the command value.

Locate Errors Quickly

"Debugging" the computer (that is, checking the electrical analog to be sure it corresponds to the equations being solved) is often a lengthy and tedious procedure. Errors in mechanization and patching are easy to make and sometimes difficult to locate. The best procedure is to calculate the value of selected variables under one or two static conditions, then test the computer to see if correct voltages appear.

For example, EASE 1100 Series computers have an operating condition known as "Static Check." In this condition the problem-solving circuit is connected exactly as at the beginning of a computing run except that suitable voltages are substituted for the output of each integrator. Theoretical values under these conditions are calculated in advance from equations or from mechanization diagrams. The calculated values are entered on a punched tape together with instructions to compare these values with those existing in the computer. The DO/IT makes the comparison: if calculated and actual values agree, it prints nothing; if there is a discrepancy, it prints the difference. An operator, scanning the printed record, can immediately pinpoint errors in patching and mechanization – in addition to errors created by possible faulty components. As an added insurance against error, this test may be supplemented by a similar check under initial conditions and a check made after an arbitrary computing time under "hold" condition.

Because automatic scanning and printout makes it easy to check a problem set-up, operating personnel are inclined to make frequent tests. These tests often expose errors which would cost hours or days of computer time if undetected.

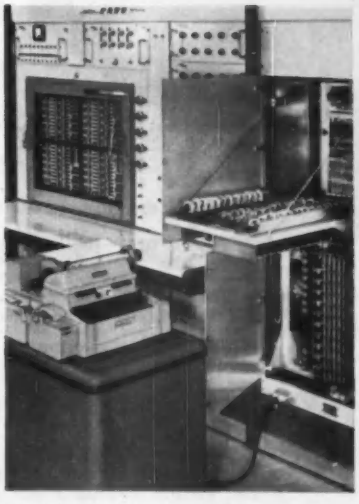
Program Survey Problems Automatically

In survey problems, equations remain essentially the same while a few parameters are changed from run to run. Solution of these problems can be speeded up by programing parameter changes on punched tape so that an entire series of computions will be run and recorded in rapid succession.

Run Two Problems "Simultaneously"

Problem handling capacity can be effectively doubled if two shifts of workers can use the same computer. Often this is impractical because one shift does not wish to destroy the set-up left by the previous crew, nor are they well enough acquainted with the problem to proceed with its solution. Punched tape entry and retrieval offer a way out of this dilemma. Each crew works on a separate problem. At the end of a shift, the people quitting work simply record all settings on punched tape and pull out the patchboard. Those coming on shift insert another patchboard and enter the previous day's setting via punched tape. In this way two projects can proceed simultaneously and without interference.

Write for further information on the DO/IT system, or better yet, see it in operation at our Los Angeles Computation Center, 305 Parkman Ave., Los Angeles 26. Kenneth Tuttle, Director.



The EASE digital control system, showing sturdy telephone-type relays which link flexowriter to digital-to-analog converter behind top panel.

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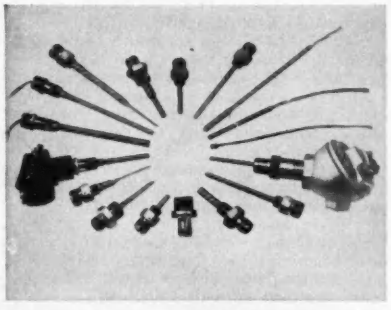

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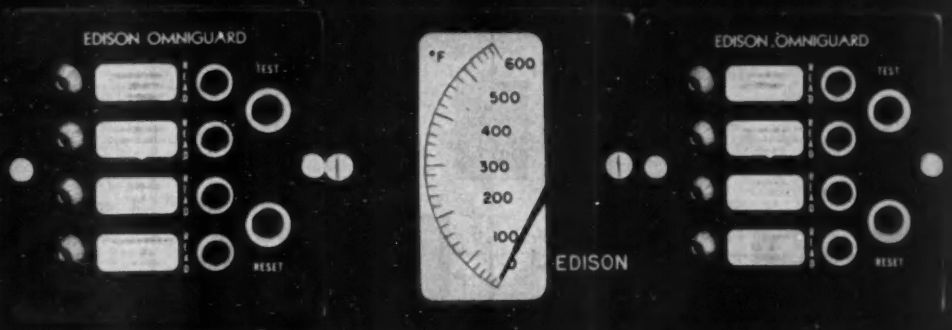

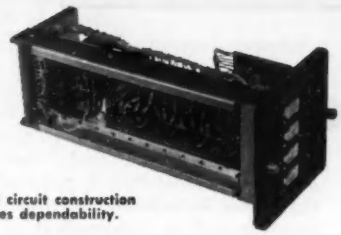

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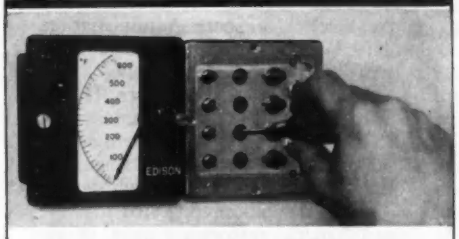
Highest quality components, with no moving parts, assure maintenance-free operation.



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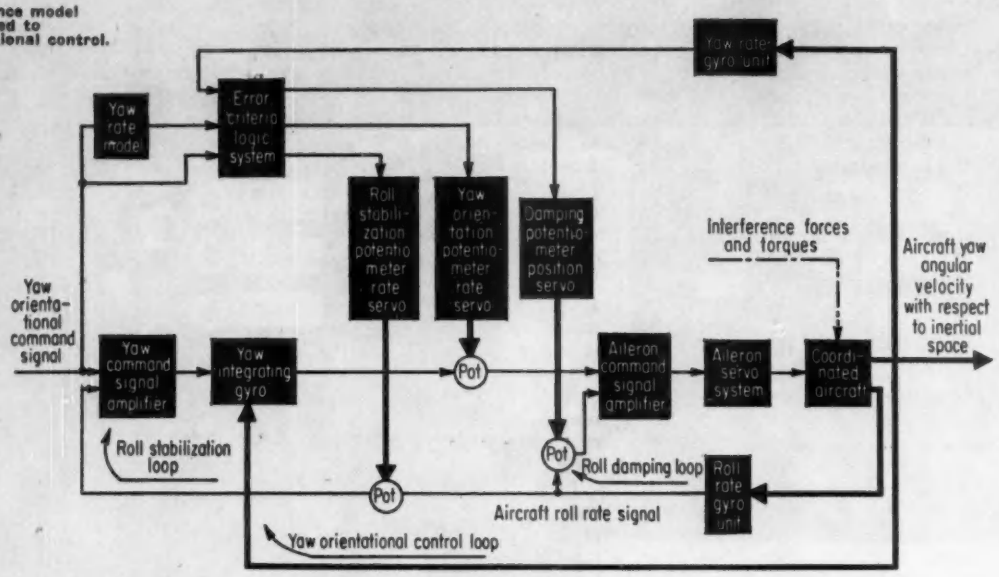
CIRCLE 18 ON READER-SERVICE CARD

MIT's reference model system applied to yaw orientational control.



Is It Adaptive Control?

The experts can't agree on a definition for it, but a sophisticated form of feedback control—with big potential in the aircraft, missile, and chemical process fields — is one of the choicest developments to watch. Here's what CtE heard at a special symposium on adaptive flight controls.

DAYTON—

The hottest subject in aircraft flight control today is adaptive controls. Proof of the interest: an unexpected turnout of over 450 control engineers at the Wright Air Development Center auditorium to hear a state-of-the-art report in a two-day special symposium. Probably generating the most heat was trouble over a definition: what is an adaptive controller?

Capt. Raymond Rath, who has been project officer for adaptive controls at WADC's Flight Control Laboratory, offered the symposium the first definition of an adaptive system: *A system is adaptive when it maintains its performance throughout the flight with closed-loop control without external data, and requires a minimum of aircraft characteristics.*

Prof. John Truxal, who chaired a morning session, felt this was too specific. Truxal's definition: *A control system which is designed with an adaptive view.* The Brooklyn Poly professor argued that all the systems discussed at the symposium (see schematics above and next page) were basically closed-loop-feedback systems. What was new was the viewpoint, which broadened the class of systems already in use.

Finally, Space Technology Laboratories' Dr. John Aseltine, leading an afternoon session, offered three criteria for Truxal's "adaptive point of view":

1. There must be a measure of system performance.

2. There must be a means of converting performance into a number.

3. There must be a means of using this number to change the system.

Though failing to agree on a definition, the gathering was almost unanimous in predicting that these new control systems have a big future, once basic studies are completed.

• **Wanted: more stability**—Despite a three-year-old Air Force program to further them, adaptive flight controls are still in their infancy. The Air Force first became interested when pilots ran into control-system stability problems on supersonic aircraft. The change in environment as the aircraft speeded up from subsonic to supersonic velocities was so large that it required practically different controls.

WADC turned to adaptive controls for more stability and for a system that would be independent of environment as well as independent of the characteristics of the airplane. The latter requirement opens up an interesting possibility. A control system independent of the characteristics of the aircraft could well be a universal control system, usable on any airplane.

This, in fact, is the objective of a U.S. Army Signal Corps program. Lt. J. B. Gilmore told the symposium that the Signal Corps was preparing a Technical Requirement for a modular adaptive controller—a computer with sensing and gain-changing capabilities. The ultimate objective: a universal autopilot.

Theoretical studies, the symposium heard, are also under way at the Ames Research Center of the National Aeronautics & Space Administration. The Ames approach: a high-gain system using an on-off controller.

• **MIT's model reference**—H. P. Whitaker of MIT's Instrumentation Laboratory described a system which has reached the hardware stage and has been successfully flight-tested. The MIT engineer suggested that the name model reference system be applied to this type of control. Its chief characteristic: the dynamic specifications for a desired system output are embodied in an analog model.

In operation, the command signal input to the control system is also fed to the model; the difference between the output signal of the model and the output quantity of the system is the

response error. Minimizing this error under all operational conditions is the objective of the adaptive portion of the system. To do it, system loop sensitivities and compensation parameters are adjusted to null or minimize selected functions of the response error signal. Such an approach, said Whitaker, avoids the uncertainties and design compromises that accompany open-loop, programmed adjustments of parameters.

One advantage of the MIT approach, said Whitaker, is it can be used to make any existing control system adaptive. Since the adaptive equipment merely makes adjustments to system parameters, failure of the adaptive equipment does not disrupt any of the signal paths of the system.

All information required to adjust parameters is obtained from the input signals that result during normal operations of the system; no test inputs are used.

• **Sperry's performance computer**—An entirely different concept was unveiled by Sperry Gyroscope Co.'s S. S. Osder. According to Osder, three techniques are used: 1) linear negative feedback for passive adaptation, 2) changing the controller's structure as a function of measured error, and 3) measuring the closed-loop response.

Behind this trio of techniques is the principle that airframe dominant poles can be overdamped by increasing the gain—if compensation elements in the flight control system are properly designed. As the gain is increased, autopilot poles become unstable instead, and the frequency of oscillation increases.

By sensing the frequency of oscillation the gain can be controlled and a predetermined frequency maintained. To do the sensing, the system is pulsed periodically and the output of the actuator measured. A specially-designed performance computer determines if the oscillations are higher or lower than the desired frequency, then corrects the gain.

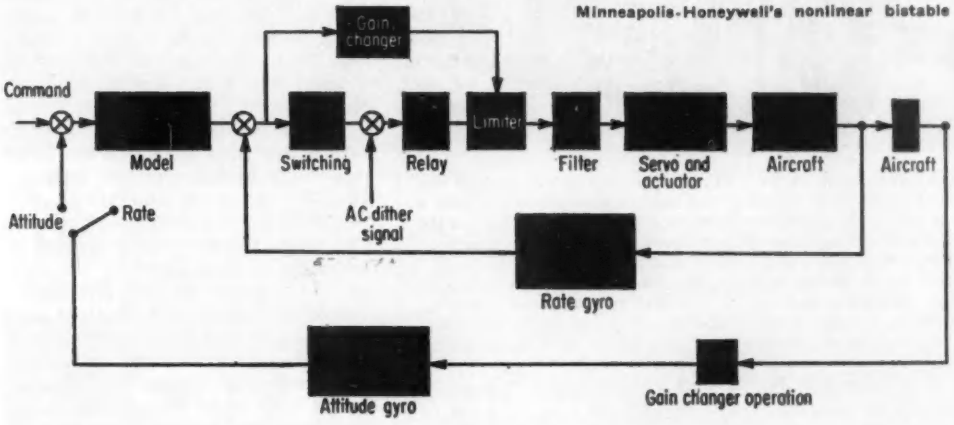
In the computer, the pulse-excited oscillations are shaped into a series of fixed amplitude pulses, fed into a logic circuit in which the criterion for autopilot gain has been established as a number of output pulses during a given sampling period. A count (determined by a magnetron beam switching tube) different than the established amount causes a gain adjustment.

• **M-H's nonlinear relay**—Still a third approach was described by three representatives of Minneapolis-Honeywell: Hugo Schuck, D. L. Mellen, and L. T. Prince. A pioneering version has already been flight-tested in an F-94C, supplying the background for an even more advanced three-axis system currently being designed for a 101A fighter aircraft.

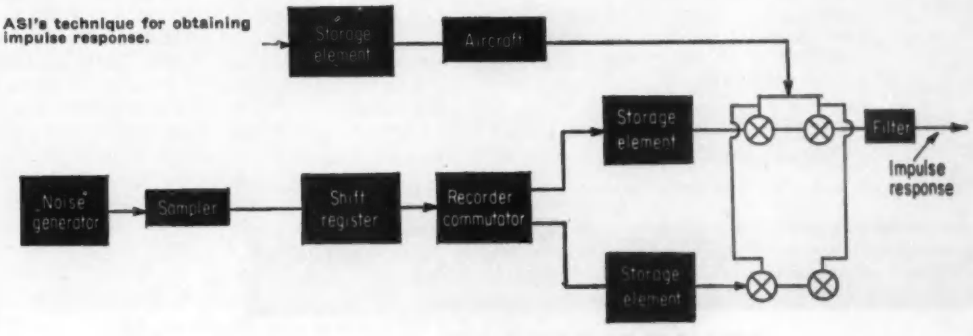
In the F-94C system, the input is applied to a model whose dynamic performance is exactly equal to the desired performance of the aircraft. The response of the model is then compared to the actual response of the aircraft; the difference becomes the input to a servo. By making the gain of the servo high enough, the response of the aircraft becomes identical with that of the model. The adaptive system boosts this gain.

Linear servo systems proved unsatisfactory because they become unstable at such high gains. So M-H tried nonlinearity of the most extreme form: the "bang-bang-type", in which full available power is applied one way or the other, depending on the direction of the switching order. The key component is a relay. Several techniques had to be developed to

Minneapolis-Honeywell's nonlinear bistable elements.



ASI's technique for obtaining impulse response.



WHAT'S NEW

curb the tendency of the "bang-bang" system to oscillate.

For the advanced control, M-H replaced the relay with a high-gain linear amplifier with limited output.

• **GE's frequency-sensitive servo**—At GE's Light Military Electronic Dept., work on the Pilot-Airplane Link (PAL) led to development of an adaptive control system; this was started about a year ago. Still in the design stages, according to GE's M. F. Marx, the system will rely on a frequency-sensitive servo to vary the multiplier gain as a function of the closed-loop frequency deviations from desired frequency.

Marx says this permits the system to control its own parameters by looking at what it is doing. The system error is led into either a lead network or a lag network, is polarized, then passes through an integrator before going to the multiplier.

• **Convair's damping feedback**—Limited by manpower, Convair Div. (Fort Worth) of General Dynamics has concentrated on the theoretical aspects of adaptive control. Two approaches have been studied: 1) applying linear feedback of position acceleration, and 2) applying the damping characteristics to modify feedback.

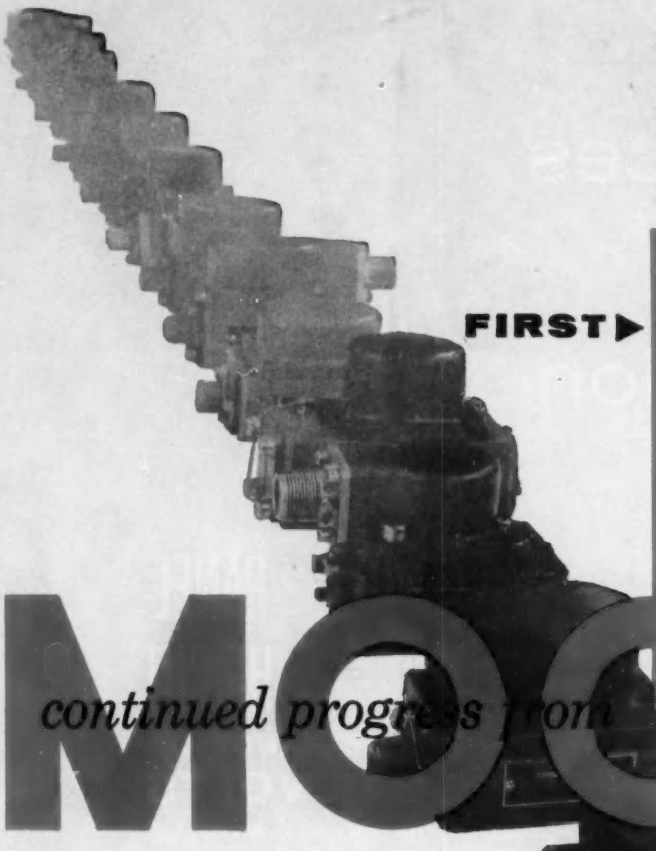
The second approach, says Convair's Marcel Dandois, looks promising. Gain adjustment is based on a measurement of aircraft-damping characteristics.

• **ASI's impulse response**—Another approach to adaptive control has been undertaken by Aeroneutronic Systems, Inc. (It was reported by ASI's G. W. Anderson and R. Buland, and Purdue's Dr. G. R. Cooper, who served as a consultant.) This approach depends on the impulse response—the cross-correlation function of the output and the input (delayed a time interval). Impulse response, say ASI engineers, completely characterizes the system, can be used to get information about damping, frequency, and sensitivity—usable to adjust gain.

To mechanize this technique, ASI has used a binary noise generator, one which produces a constant amplitude signal with random time crossings. The sampled noise is fed through a shift register to a recorder commutator, past diode gates, and finally is time-averaged in a filter. The output of each filter is one point on the impulse-response curve.

The theory, say ASI engineers, is valid for a linear system. How accurate it is for a nonlinear system has to be determined.

—Lewis H. Young



DESIGN

As missile programs passed from early development to production, servovalves of increased sophistication became necessary. Keeping pace with this development, Moog has been responsible for all major servovalve improvements.

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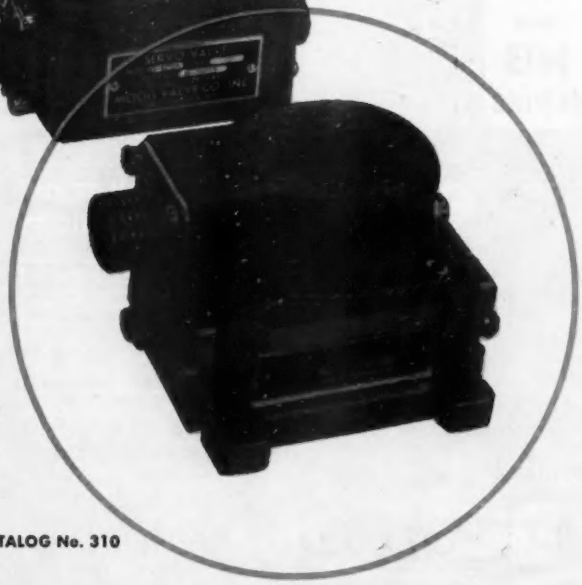
PRODUCTION

The 80,000 Moog servovalves produced to date represent a production record unmatched in the industry. Moog is the major supplier to virtually all missile programs.

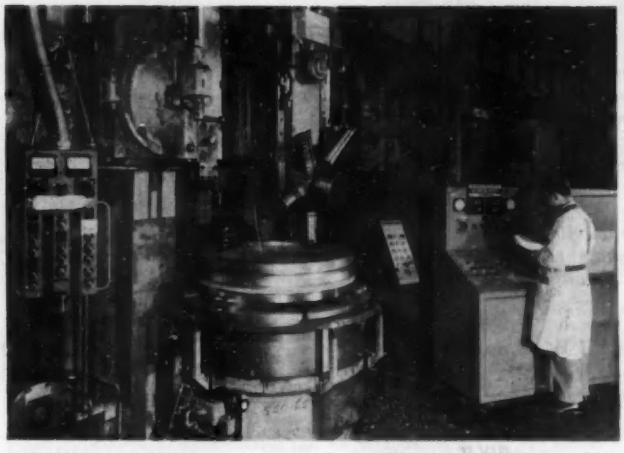
RELIABILITY

Today reliability is the key requirement for missiles. Anticipating this need, Moog has had under intensive development and test for the past year the simplest, lightest, most compact and reliable of all production servovalves. Its performance in all important respects exceeds that of any other available unit. Moog is pleased to announce immediate availability of the new Model 31 and 32 Series valves in quantity to your specifications. ▶

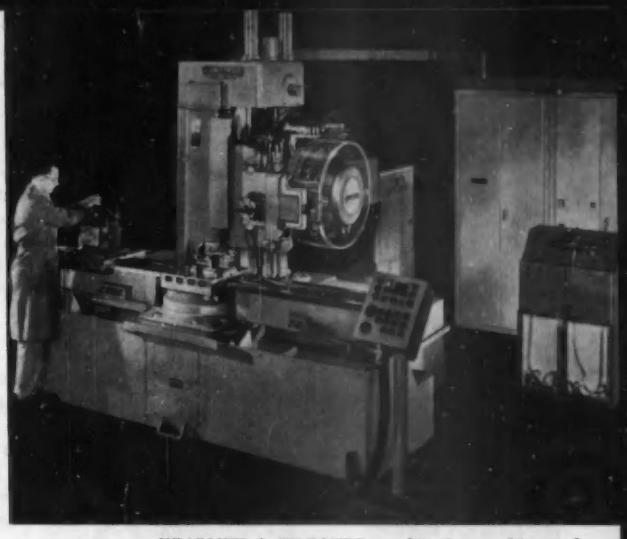


WRITE FOR CATALOG No. 310

MOOG VALVE CO. INC. PRONER AIRPORT, EAST AURORA, NEW YORK



GIDDINGS & LEWIS puts tape control on a 54-in. vertical boring machine.



KEARNEY & TRECKER combination machine tool with GE discrete positioning control (at right).

Two New Developments in Numerical Control

Machine tool builders move to get numerical control into general-purpose equipment. G&L puts tape controls onto two conventional machines; K&T comes up with a radical new machine tool.

With the Air Materiel Command's purchase of numerically controlled skin and spar mills just about complete, machine tool builders are working hard to find other applications for their advanced techniques. The problem: to get numerical controls into general-purpose equipment with appeal for users in all branches of industry.

The first major breakthrough came last month when the two companies that supplied the greater share of AMC's total requirement for skin and spar mills demonstrated new machines (see photos). Giddings & Lewis Machine Tool Co. had two: a vertical boring mill, and a vertical turret lathe. At the same time, Kearney & Trecker Corp. proudly displayed its entry into the tape-control sweepstakes: a multi-function hybrid manufacturing machine with the name "Milwaukee-Matic".

• **G&L's approach**—Both G&L machines have been made by the company for some time, although without tape controls. Both are turning machines, similar in basic machining concept: the workpiece is fastened to a continuously rotating table while cutting tools are fed in from above and from either side.

The vertical boring mill has a tape-controlled turret tool head capable of simultaneous vertical and horizontal movement. It is thus suitable for contouring the inner and outer surfaces of round parts.

The numerical control system is substantially the same G&L—General Electric design used in the AMC skin and spar mills. The control medium is magnetic tape that is prepared by means of a digital computer and director. G&L heralds the machine as the first application of numerical path control to a turning machine and the first outside of the aircraft industry. Gray Tool Co. has purchased the initial unit for machining oilfield valves.

• **Vertical step cutter**—The G&L vertical turret lathe is intended for step-cutting only, not contouring. It is aimed squarely at the market dominated for years by Bullard lathes equipped with Man-Au-Trol (a peg-and-drum programmer).

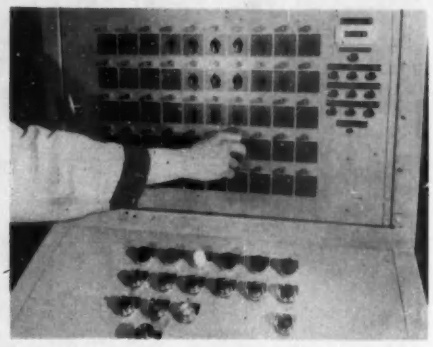
For the machine, a G&L task force headed by Arthur Fitzner has designed and built its own punched-tape point-to-point positioning system. A key feature: an override adjustment panel with 50 potentiometers, each of which is associated with one position command on the input tape. Using the potentiometers, the operator can change any or all of the height or radius commands by plus or minus 0.010 in. in small increments. This feature makes it possible to compensate for unpredictables such as tool wear or deflection—without disturbing the input tape.

• **Milwaukee-Matic acceptance** — If sales success is any criterion, the K&T Milwaukee-Matic is unquestionably the most spectacular machine in the young history of numerical controls and, in fact, in the recent history of the machine tool business. Twenty-five of the $120,000 units had already been ordered before the first delivery was made late in February.

Trial runs on the prototype unit showed such decided economic benefits and aroused such fervor in a sample group of prospective users that K&T's president, F. J. Trecker, has ordered full-scale production. Schedules call for 60 machines in 1959, 200 in 1960, and 600 in 1961.

The combination machine is capable of milling, drilling, reaming, tapping and boring operations. It is actually the second step in the evolution of "a parts manufacturing machine". The first step, demonstrated about two

WHAT'S NEW



Bank of 50 potentiometers on G&L point-to point control permits operator to modify tape data.

years ago, consisted of three separate K&T machines, joined by a transfer line and controlled by a Hughes Products Co. punched tape system (CtE, April 1958, page 21). Like the three-machine arrangement, the Milwaukee-Matic is designed to automate the production of small- and medium-lot parts. But it requires far less capital investment to do so. K&T's Wallace E. Brainard was key man in the development of Milwaukee-Matic.

• **Automatic tool changer** — The principal feature of the machine is an automatic tool changer that makes possible the great variety of machining operations. A General Electric punched-tape system controls tool selection, the indexing of the worktable, the positioning of the three-axis spindle head, feeds and speeds, and auxiliary functions.

For longitudinal and vertical positioning, absolute positioning accuracy is plus or minus 0.0005 in. and repeat accuracy is plus or minus 0.0002 in. Spindle depth positioning is accomplished at an absolute accuracy of plus or minus 0.001 in. and at a repeat accuracy of plus or minus 0.0003 in. The machine will perform circular cutting of radii from 0.1 to 9.9 in. in radius increments of 0.1 in. The maximum error on arc milling is plus or minus two percent of arc length. Maximum speed for arc and slope cutting is 30 ipm for radii between 0.5 and 9.9 in.

Spindle speed and feed rate commands are selected by precision resistor networks for servo control from tachometer feedback. A small instrument analog computer, approximately 10 by 20 in., does all the interpolation required for arc and slope generation. This process is started, controlled, and stopped automatically from four instruction blocks on the tape.

—John D. Cooney

CIRCLE 23 ON READER-SERVICE CARD →

H. J. Birchal

are you fighting SPACE?

No need to suffer from engineering claustrophobia, if you design with CANNON PLUGS in mind!

Cannon Miniature and Sub-Miniature Plugs are rugged, easy mating, unusually versatile, neat and compact. When you design with Cannon Miniatures in mind you'll get complete electrical circuit dependability in a very small space. Up to 50 contacts in ½ or ⅓ the area taken by standard multi-contact connectors!

Rectangular and circular types. Hermetically sealed, vibration and moisture resistant, and general purpose designs. Contacts for 5, 10, 15, 25 amps . . . and miniature coaxial connectors. Practically all five ampere contacts are gold plated. High dielectric insulation in phenolics, resilient materials, glass seals, Zytel, Diallyl Phthalate and Melamine. Aluminum alloy or steel shells, depending upon application.

Miniature lines include: DPA, DPX, DPM, DPG, K, MM, MR and Diamond MB and SM Coaxial connectors. **Sub-miniatures:** D, MC, and Diamond DIC Coaxial connectors.

Write TODAY for new 32-page 2-color Miniatures Bulletin HMC-2. Also, write for Bulletin SM-1, "Soldering Small Contacts."

For an interesting discussion of the broad subject of "Reliability," write for Cannon Bulletin R-1.

CANNON PLUGS

WHERE RELIABILITY IS THE 5TH DIMENSION

AWARENESS OF PROBLEMS · INTEGRITY OF INTENT · DESIGN EFFORT · MANUFACTURING CONTROL

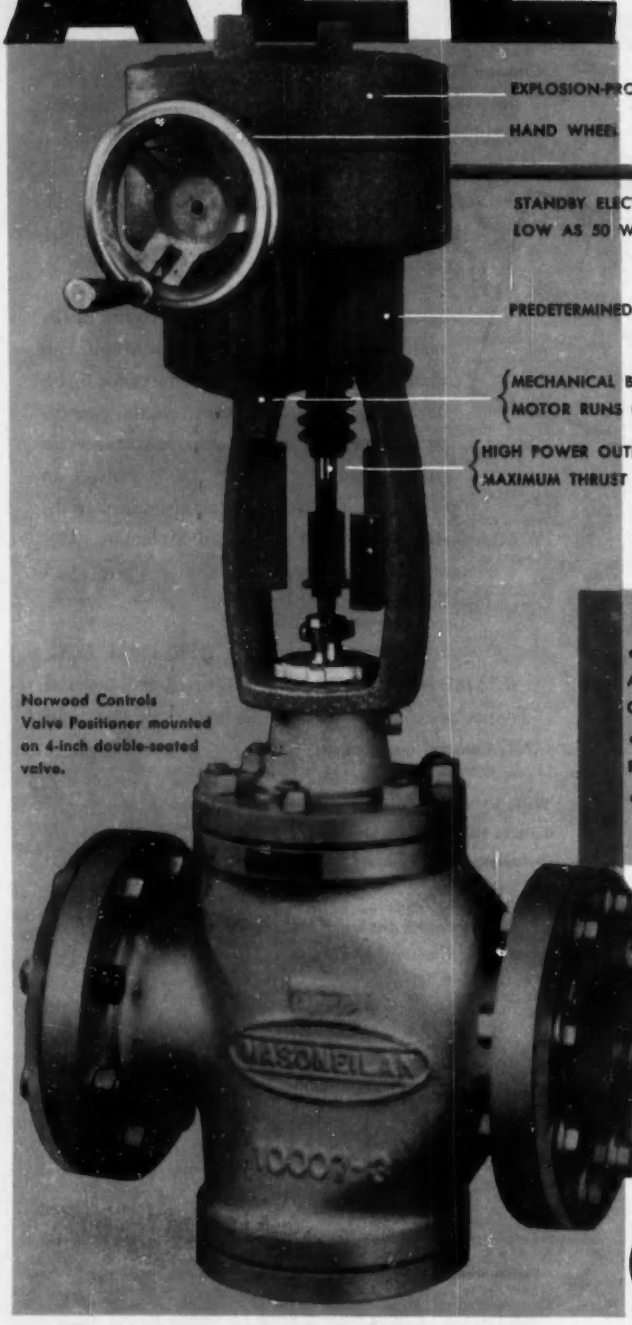
Please refer to Dept. 422

CANNON ELECTRIC CO., 3208 Humboldt Street, Los Angeles 31, California. Factories in Los Angeles; Salem, Massachusetts; Toronto, Canada; Melbourne, Australia; London, England. Manufacturing licensees in Paris and Tokyo. Representatives and distributors in all principal cities. See your Telephone Yellow Book.

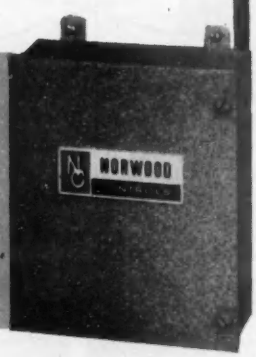
NO OIL – NO AIR . . . NORWOOD CONTROLS

VALVE POSITIONER IS

ALL ELECTRIC



Norwood Controls Valve Positioner mounted on 4-inch double-seated valve.



- ADAPTS TO SIGNAL FROM ANY AVAILABLE ELECTRIC CONTROLLER
- MERCURY WETTED POWER RELAYS—VIRTUALLY INFINITE LIFE
- ADJUSTABLE STROKES ½" TO 2"

Maintenance problems drop almost to zero when you install Norwood Controls' new all-electric Valve Positioner. No air or hydraulic leaks, no cleaning, no expensive auxiliary equipment . . . just one, efficient, pre-lubricated, all-electric unit that operates from −40°F to 170°F.

For further information, write for data sheet B158-5. Norwood Controls Unit, Detroit Controls Division, 938 Washington Street, Norwood, Mass.

AMERICAN-Standard
DETROIT CONTROLS DIVISION

 CIRCLE 24 ON READER-SERVICE CARD

Purdue-CtE Conference:
A Practical Program for Industrial Control

How to apply some of the newest developments in components is the core of the program (see below) for the 1959 Conference on Industrial Control System Components.

Co-sponsored by CONTROL ENGINEERING and Purdue University's School of Electrical Engineering and the Division of Adult Education, the conference will be held on Monday and Tuesday, May 4 and 5, at Purdue's Memorial Center in Lafayette, Ind.

The two-day meeting has been divided into four working-level sessions. Purdue's Dr. John E. Gibson will chair the Monday morning session on actuators. CtE's W. E. Vannah will lead the session on power amplifiers. Heading the Tuesday morning session on transducers will be Dr. Rufus Oldenburger, professor at Purdue's Mechanical Engineering School. And CtE's B. K. Ledgerwood will chair the closing session on logic and decision-making elements.

Registration fee for the meeting has been set at $35. It includes admission to all sessions, a copy of the proceedings, and a banquet dinner on Monday evening. For additional information, write Merle M. McClure, Assistant Director, Div. of Adult Edution, Purdue University, Lafayette, Ind.

PROGRAM

Conference on Industrial Control System Components

I. ACTUATORS (Monday morning)

Integral HP dc Servomotor Developments
by V. R. Murphy
Mgr. VS and Control Prod. Dept., Reliance Electric & Eng. Co.
When designing servomotors from the total system viewpoint, not only the load but also the power source is of critical import. Both dynamic and static performance have to be considered.

Selecting Variable Displacement Hydraulic Pumps
by R. Spencer
Assistant Chief Engineer, Machinery Hydraulic Div., Vickers, Inc.
Operating characteristics, emphasizing dynamic response and load characteristics, are considered to select variable displacement hydraulic pumps for automatic control. A new line of variable displacement piston pumps for industrial systems has been developed.

The Power Stepping Motor as a Digital Actuator
by W. R. Gracey
Mgr., Automatic Controls Div., The Teller Co.
Responding to a string of pulses, the power stepping motor combines actuating power and accurate control without feedback. The stepping motor lends itself to use in numerical control tool systems, plotting and tracking systems, as a remote actuator or positioner, and as a computer component.

II. POWER AMPLIFIERS (Monday afternoon)

High Pressure Pneumatic Systems for Industry
by A. E. Schmidlin
Mgr., Research Dept., Walter Kidde & Co.
Development work is under way on high-pressure (5,000 psi) components for industrial control systems. There are applications in manufacturing and processing plants and in operating machinery.

Using Magnetic Amplifiers in Control
by Dr. C. Wakeman
Director of Research & Development, Magnetics, Inc.
Magnetic amplifiers can be used in control systems as power amplifiers and as logic elements. Dynamic response, input-output characteristics, and physical properties — such as size and materials — are analyzed for a number of useful circuits.

The Capstan-Type Mechanical Power Amplifier
by L. A. Zahorsky
Avionics Dept., Armament Div., Universal Match Corp.
Driven by a constant-speed motor, the bidirectional capstan-type mechanical power amplifier can supply high power levels for position or speed control with a low level mechanical input such as is available from an instrument servo. Six widely diversified applications suggest solutions to other control problems.

Characteristics of the Acceleration Switching Servo
by Dr. W. Seamone
Applied Physics Laboratory, Johns Hopkins University
The acceleration switching technique can enhance hydraulic servo system performance in applications requiring precision and reliability over a wide range of load and environmental conditions. A study of static and dynamic performance of a switching-type system indicates where it improves on conventional flow control servo.

III. TRANSDUCERS (Tuesday morning)

Characteristics of Position Measuring Transducers
by J. O. Morin
Project Enginer, Concord Control, Inc.
Position measuring transducers fall into four general classes defined by the fundamental principle of operation: electromagnetic, electrostatic, optical, or electromechanical. To illustrate important considerations of using each, several practical applications in industry are described and discussed.

Multipurpose Technique: Measuring with Eddy Currents
by Richard Hochschild
President, Metrol, Inc.
How to use eddy currents for flow detection and classification in such products as ferrous and nonferrous tubing, bars and wire rope; for the gaging of sheet and glue line thickness; and for checking metal properties such as hardness, alloy composition, and heat treatment.

Transducers for Dynamic Flow and Measurement
by Dr. C. K. Sledman
Consultant, Statham Instruments, Inc.
For proper control of operations, the transducer must be capable of detecting and transmitting dynamic as well as static conditions. Because flow and pressure are particularly difficult to measure properly, the characteristics and capabilities of these and other transducers pose a special problem. How they perform is important knowledge for the control engineer.

How to Pick and Use Proximity Switches
by J. M. Morgan
Mgr., Development Research Dept., The Cincinnati Milling Machine Co.
Proximity switches, sometimes used in place of limit switches, have proven their worth and reliability on many difficult jobs. But to get the most from them requires a knowledge of the pros and cons of the various types and an awareness of their basic application factors. Here is an evaluation.

IV. LOGIC ELEMENTS (Tuesday afternoon)

Building Blocks for Automatic Test Equipment
by J. J. Brett
Chief Engineer, Chicago Div., American Bosch Arma Corp.
Automatic evaluation systems that pronounce go/no-go judgments on performance characteristics of the equipment under test, are almost always custom designed for each job. But this is not necessary. Properly conceived functional subsystems can be used as building blocks for a wide variety of production test gear with minimum engineering and at minimum cost. Here is one approach with a wide potential application.

The Controlled Rectifier—A New Industrial Control Concept
by E. E. Von Zastrow
Application Eng., Semiconductor Prod. Dept., General Electric Co.
The silicon controlled rectifier is making possible vast strides toward completely solid-state control systems. Here are details of cost and availability, performance characteristics, firing methods and related system components, and of applications — both as a switching device and as a proportional power modulator.

AIEE Meeting Highlights

- *That Elusive Adaptive Concept*
- *Russian Education and Technology*
- *New Approach to Feedback Controls Sessions*

Adaptive Control: Still No Unity

The old bugaboo, "what's an adaptive system" page (22), provided the main bone of contention at the Feedback Control Systems Committee session on adaptive control systems. And despite a lengthy discussion period, none of the definitions offered could satisfy the critical view of all those in attendance.

All four papers formally presented were highly theoretical. Dr. C. W. Merriam III, MIT, offered a paper entitled "Use of a Mathematical Error Criterion in the Design of an Adaptive Control System". Merriam applied a restrictive definition of adaptive control: a feedback controller that maintains optimum response by minimizing defined error. What error to use then was the kernel of his paper. Merriam's suggestion:

$$e = \int_t^{t+\tau} \left\{ \lambda(\sigma)[Q(\sigma) - q(\sigma)]^2 + m^2(\sigma) \right\} d\sigma$$

J. E. Bertram of IBM Corp. delivered a paper "Control by Stochastic Adjustment". He described a statistical technique which could be used when time variations are too short for normal statistical approaches.

"Is this an adaptive system?" was the question G. F. Franklin, Stanford Research Institute, asked about a control system which he described. The system: a solution to the sample-data filtering problem. The second part of Franklin's paper was an attempt to clarify the definition of adaptive control. To do this, Franklin classified control systems on the basis of the mathematical properties which describe their behavior. He proposed seven groupings: 1) linear, lumped, time-invariant, 2) linear, sampled, 3) digital, 4) linear, time-variant, 5) self-organizing, 6) probabilistic, and 7) nonlinear.

The Stanford engineer placed adaptive control in the group which he called 'probabilistic" because such a system, he said, cannot be described in determinant form. He explained, "The word adaptive implies that, in some sense, the design was incomplete, and the adaptive system was expected to fill in the details."

In the final paper Robert Staffin of Polytechnic Institute of Brooklyn introduced the "Executive-Controlled Adaptive System". This is a system which can be process adaptive, input signal adaptive, or a combination.

For process adaptive systems (those in which the controller must adapt to changes in the process) Staffin employed a plant observer which would report to the controller changes in the process. To do this, he proposed two types of mechanization. One used a frequency response approach. The objective: to design the actuator so that it cancels only the effects of the dominant pole pair. The plant observer measures the approximate pole location and then chooses an appropriate fixed passive network to cancel the dominant pole pair.

Staffin's other approach used impulse response. White noise is added to the process input; the process output is then cross-correlated with the noise delayed by a constant time. In this way it is possible to determine the approximate pole location so that the dominant pole pair can be cancelled.

For input signal adaptive systems, Staffin suggested a model (which he did not describe in detail) whose function would be to force the output of the system to act as desired.

Russian Education: A Plea for Calm

"I hope we won't push the panic button and revolutionize our educational system to turn out better Russians," Dr. W. W. Brickman of New York University told the AIEE session on Russian Education and Technology. The five other speakers at the session echoed this sentiment. The consensus: Russian engineering education is good, but it has some clear weaknesses.

While pointing out the strengths of Russian education—serious concentration for five years of tough courses; a strong interest in foreign languages —most Russian engineering students study two; and a large enrollment—

CIRCLE 26 ON READER-SERVICE CARD →

New ALLEN-BRADLEY Power Ferrites for Audio Frequencies (400 to 15,000 cps)

With the development of these two new power ferrites, it is now possible for you to gain the advantages of high-efficiency operation at the lower frequencies. These new ferrites are available in a wide range of shapes and sizes. A-B engineers will be glad to assist you in the application of these new ferrites.

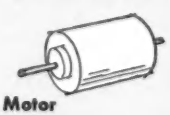
W-07 **NEW POWER FERRITE** *with maximum flux density in excess of 5000 gauss* — Here's an A-B ferrite that opens new fields for the use of ferrites in continuous power applications at frequencies between 400 and 15,000 cps—where even special laminated iron alloys are impractical. And its lower material costs bring tremendous savings in high-frequency fluorescent lighting ballasts, power transformers, motors, and high-frequency converters.

R-03 **NEW POWER FERRITE** *has rectangular hysteresis loop* —The many unique properties of this R-03 ferrite offer unusual opportunities for designing intermediate frequency magnetic amplifiers, static switching devices, transistorized inverters, and power supplies. At operation above 500 cps, the cost and weight of this new ferrite is less than one half that of square loop, metallic tape wound cores . . . and core losses are much less. In addition, the extreme squareness of the hysteresis loop minimizes transient spikes which can damage transistors.

Typical Applications for Allen-Bradley Power Ferrites

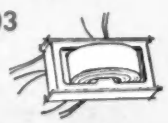
W-07

HF Fluorescent Lighting Ballast

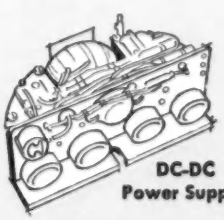


Motor

R-03



Transistor DC Power Supply Transformer



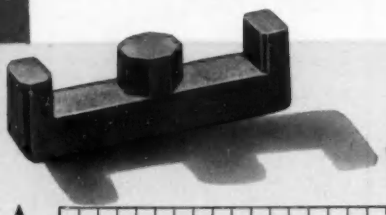
DC-DC Power Supply

Allen-Bradley Co., 222 W. Greenfield Ave.
Milwaukee 4, Wis.
In Canada: Allen-Bradley Canada Ltd., Galt, Ont.

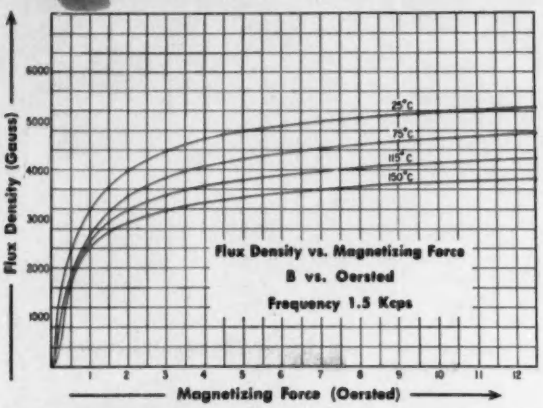
ALLEN-BRADLEY Electronic Components

1-59-8

New Allen-Bradley Power Ferrites Open New Design Horizons



W-07

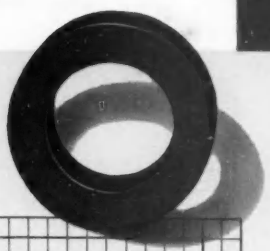


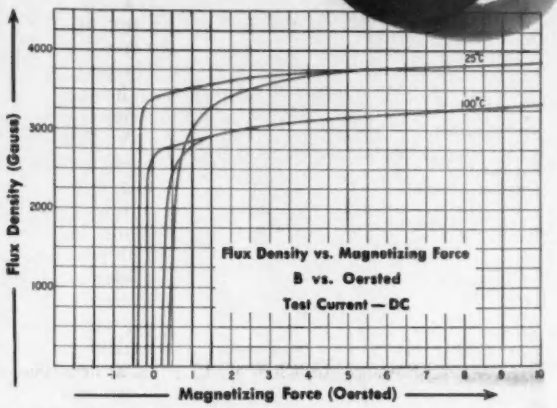
W-07 MAGNETIZATION CURVES show the extremely high flux density available. Also, it reveals that the maximum flux density does not decrease appreciably in increasing temperature. Technical Bulletin 5655 has complete specifications–send for your copy.

TABLE OF MAGNETIC PROPERTIES (TOROIDAL)

Property	Symbol	Unit	Nominal Value	Test Current
Sat. Flux Density @ 10 Oersted	B_s	Gauss	5,200	1.5 Kcps
Residual Mag.	B_r	Gauss	1,000	1.5 Kcps
Coercive Force	H_c	Oersted	.24	1.5 Kcps
Initial Permeability	μ_o	—	1,300	1.5 Kcps
Maximum Permeability	μ_{max}	—	4,000	1.5 Kcps
Curie Point	CP	+ °C	280	—

R-03





R-03 HYSTERESIS LOOPS show the high flux density provided with low levels of drive. The reduction in area with temperature shows that the loss per cycle is less at higher temperatures. For complete specifications, write for Technical Bulletin 5658.

TABLE OF MAGNETIC PROPERTIES (TOROIDAL)

Property	Symbol	Unit	Nominal Value	Test Current
Sat. Flux Density @ 10 Oersted	B_s	Gauss	3,900	D.C.
Residual Mag.	B_r	Gauss	3,360	D.C.
Coercive Force	H_c	Oersted	.37	D.C.
Initial Permeability	μ_o	—	325	1.5 Kcps
Maximum Permeability	μ_{max}	—	3,500	1.5 Kcps
Maximum Differential Permeability $\left(\frac{\Delta B}{\Delta H}\right)_{B=0}$	μ_d	—	40,000	D.C.
Switching Time @ 2.5 H_c	t_s	μ sec	2.9	—
Curie Point	CP	+ °C	315	—

Allen-Bradley Co., 222 W. Greenfield Ave., Milwaukee 4, Wis.
In Canada: Allen-Bradley Canada Ltd., Galt, Ont.

1-59-E

ALLEN-BRADLEY
ELECTRONIC COMPONENTS
QUALITY

WHAT'S NEW

the panelists warned that there were weak points, too. The most obvious: Russian concentration on specific areas is so intense that engineering graduates are quite narrow in their knowledge.

L. Trilling of MIT told the meeting that the Russians had 600,000 students in their engineering schools, would graduate almost 85,000 per year (compared to U. S. graduations of 35,000). But Trilling warned about playing the "numbers game" indiscriminately. Many Russian engineering graduates never do engineering work he said. Because there are no schools of business administration, engineering graduates end up doing jobs in finance, accounting, marketing, and other administrative areas.

V. Rudolf, a Russian engineer now living in New York, strongly supported this view. Said Rudolf, "There's a terrific overhead in engineering personnel in Russia. At some plants it is 150 percent: 1½ engineers for every workman". Rudolf told about the electrical department of a shipbuilding organiaztion for which he had worked in Leningrad. "In the electrical department, there were 50 engineers, of which 25 were administrators who did no engineering work."

The speakers agreed that it would be dangerous to underestimate Russian technical capabilities.

Feedback Control Systems: Committee Goes Technical

Something new has been added to the AIEE Feedback Control Systems Committee meetings. At the Winter General Meeting informal technical presentations replaced routine business. The change was the result of a redefinition of Committee objectives and a realignment of Subcommittees recommended by an ad hoc subcommittee under H. T. Marcy.

In the future, regular business will be transacted mainly by executive and administrative subcommittees. The programs of the full committee meetings will be organized by technical subcommittees each devoted to such specific areas of the control field as non-linear theory, discrete data systems theory, and computers.

Chairman Lou Kazda of the nonlinear theory subcommittee organized the program at the Feb. 4th meeting. It included six informal papers on various phases of nonlinear systems analysis and synthesis. Apparently the idea of technical presentations scored a hit: about 40 committeemen were present.

CIRCLE 29 ON READER-SERVICE CARD

WHAT'S NEW

Single order-picking console.

Electromechanical Order Picker

. . . and automatic depalletizers mechanized a California egg plant, boosted production 50 percent.

SAN FRANCISCO—

The only system of automatic warehousing in an egg-processing plant has boosted hourly production 50 per cent. At Poultry Producers of Central California's new San Leandro plant, 2 million eggs are processed early each day. Combining for the first time electromechanical order pickers and automatic depalletizers, the new materials handling equipment mechanizes a process which used to be largely a manual operation. All equipment was built by the Egg Handling Section of Food Machinery & Chemical Corp., Riverside, Calif.

Filling orders—Order picking is controlled from a single console. Push buttons set up a series of relays which automatically discharge cases from one of 36 double-decked, gravity roller order picking lines (where cases have been stored according to brand and date) to double-decked belt take-out conveyors. Cases are carried on movable roller conveyors to the docks outside to be manually loaded into trucks.

Upper buttons on the console control ten-count, and lower buttons control unit count. To fill an order, the operator presses selector and start buttons. An air-operated case-stop at the end of an order-picking conveyor is depressed, and the case moves onto the take-out conveyor. There it passes the case stop reset switch and the cycle is repeated until the order from that line is completed. Then the next line in sequence begins to deliver cases. An indicator light on the console signals completion of the order, and the op-

the first real "BREAK" for airborne harnesses

THE ALL NEW A-MP HELICON CONNECTOR

FEATURES

- helical construction imparts a connection so firm that a special A-MP tool is required to connect and disconnect.
- "o" ring and metal wire-insulation ring make moisture-tight seal
- wiping action cleans pin and socket for assured maximum conductivity
- positive wire-stops prevent over-insertion of stripped conductor

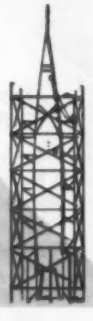
FEATURES

- serrations inside barrel assure maximum crimp-contact between barrel and conductor
- inspection ports permit examination of conductors in barrel
- environmental proofing: moisture resistant, corrosion resistant, vibration and shock resistant

Never before has such a unit been available—a reliable, pre-insulated "manufacturing break" for aircraft and missile harnesses. Designed as a quick connect/disconnect for all high-reliability circuits, the all new A-MP HELICON Connector is completely environmental-proofed and fully pre-insulated. Equally important, it requires a special A-MP tool to connect and disconnect, thereby preventing tampering and unintentional breaks in circuits.

The HELICON Connector can be attached to airborne circuit wires with remarkable speed and ease . . . permits multiple connect/disconnects without harm to unit . . . offers the highest reliability.

Visit us at The IRE Show March 22-26, 1959 Booths 2234-2238



This is the product that the Avionics Industry has needed for years. There is nothing else on the market like it. Write for more information.

AMP INCORPORATED

GENERAL OFFICES: HARRISBURG, PENNSYLVANIA

A-MP products and engineering assistance are available through subsidiary companies in: Canada • England • France • Holland • Japan

CIRCLE 30 ON READER-SERVICE CARD

erator resets for a new order. **Keeping order lines filled**—Two automatic depalletizers patrol the order-picking lines and fill them from loaded pallet conveyors. They travel by rail at 2 mph, each serving 18 double-decked order-picking conveyors.

As an order-picking line is depleted, the depalletizer stops and is locked into position by an hydraulic centering pin. The boom normally is level with upper order-picking lines, but will descend to serve lower lines. Forks raise the pallet to the boom, and the hydraulically-operated boom carriage moves out, and suction cups pick up three cases. These are moved into position over the roller conveyor, the vacuum is released, and the cases are conveyed to the order-picking line.

The process is repeated until the empty line is filled; then a switch on the boom actuates a finish relay, and the carriage pushes the empty pallet board onto the gravity conveyor to be returned to the loading area. The depalletizer is unlocked and starts on its patrol again.

The console operator has some control over depalletizers. When he actuates a grade selector switch in combination with a priority switch, the depalletizer will ignore earlier demands and serve only one order-picking line. To handle a large order, he can lock the depalletizer from the console to continue delivering from one conveyor to order-picking lines until the order is filled.

—Jenness Keene
McGraw-Hill News

More Computing-Control

Two more chemical companies have bought digital computers for control of chemical processes. Both companies emphasize that their machines, Thompson-Ramo-Wooldridge Products RW-300's, will be used for closed-loop control.

In St. Louis in January, Monsanto Chemical Co. Vice-President Howard K. Nason announced, "To the best of our knowledge, this will be the first chemical plant to use an electronic computer for direct, on-line control of the overall process. It will be installed in an existing manufacturing unit, already highly instrumented."

Two weeks later, in Cleveland, B. F. Goodrich Chemical Co. President John R. Hoover reported an RW-300 will exercise closed-loop control over a fully-automated vinyl chloride monomer production unit at Goodrich's Calvert City (Ky.) plant. The machine will also log operating data.

- **Flat frequency response** from 0 to 100 cps
- **Galvanometer** natural frequency 55 cps
- **Hysteresis less than ± 0.1 div.**
- **True velocity damping** for galvanometer at all times — limiting ahead of output stage
- **Current feedback power amplifiers** eliminate effect of galvanometer resistance changes due to temperature
- **Linearity 0.2 div.** over entire 50 div. chart width
- **Gain stability** better than 1%
- **Base line drift less than 0.2 div.** over 20°C. changes
- **Automatic stylus heat control**
- **Inkless recording** in true rectangular coordinates

PERFORMANCE

is the best proof of SANBORN "350" System Quality

8-CHANNEL SANBORN "350"
Direct Writing Oscillographic Recording System . . .
also available with 6 channels

Only the Sanborn "350" oscillographic recording system offers *both* superior performance *and* operating versatility. You can interchange the plug-in preamplifiers — or use them separately with their own power supplies to drive a scope, meter, or optical oscillograph. The compact recorder (17½ inches tall), complete with transistorized power amplifiers and power supply, may also be used separately (sensitivity 0.1 volt/chart division). That's real versatility!

Recorder features include built-in paper footage indicator, paper take-up, 8" of visible record, simple paper loading from the front. Nine electrically controlled chart speeds are selected by pushbuttons, and have provision for remote control. Connections are also provided for output monitoring.

All these features — plus well-known Sanborn reliability — are yours in the Sanborn "350" system. Ask your local Sanborn Industrial Sales-Engineering Representative for complete facts — or write the Industrial Division in Waltham.

At the I.R.E. Show — Booths 3601-3605

SANBORN COMPANY
175 Wyman Street, Waltham 54, Mass.

CIRCLE 32 ON READER-SERVICE CARD

WHAT'S NEW

The Vacuum Tube Fights Back

Development of the cold cathode gives the vacuum tube new life in its market battle with transistors.

For the past two years, makers of vacuum tubes have watched some of their best user customers move into the fold of transistor suppliers. The trend to transistorization has been pushed by the requirement for increased reliability, a desire to ease the cooling problem, and the need to cut down the power requirements of electronic equipment.

A research program which, till now, cost less than $200,000, has given the vacuum-tube makers an answer to some of the advantages of transistors and has produced one of the most significant component developments in recent years: the cold cathode for gasless vacuum tubes.

Both the U.S. Army Signal Corps and Tung-Sol Electric, Inc., have worked on this development. To Dr. Dietrich Dobischek, scientist at the Signal Corps' R&D Labs, goes credit for the initial breakthrough. He first discovered the ability of a magnesium oxide coating to sustain secondary electron emission with no external stimulus. In July 1956, Tung-Sol, under contract to the Signal Corps, started to develop and improve this magnesium oxide cathode.

Last month, Tung-Sol engineers demonstrated the first practical application of the cold cathode—a 900-mw audio output tube. One of the most interesting aspects of the development: the ease with which this and similar tubes can be put into production. According to Dr. A. M. Skellett, Tung-Sol's director of research, manufacturing processes would be almost identical with those currently used for the hot-cathode tubes. Costs then would be about the same.

Other obvious advantages of the cold-cathode tubes over the heated types include:

- A much lower cathode power requirement—the tube demonstrated drew 1/10th the cathode power required by a similar hot-cathode tube
- faster starting—the cold cathode reaches full output in a fraction of a second
- much longer life—one of the early tubes has been in continuous operation for over 14,000 hours with no noticeable decrease in the emission.
- noise level and some other char-

Unique combination of performance, size and price

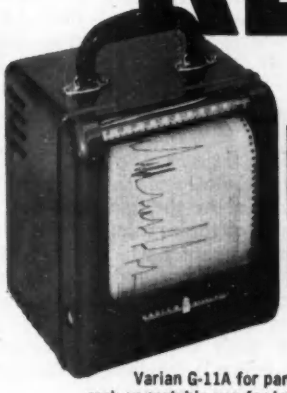
OVER 1000 TIMES AS SENSITIVE as galvanometer recorders. . . and Varian's null-balance potentiometer needs no power from the source being measured. Rugged, stable mechanism allows ink or inkless recording — easy-to-read rectilinear chart — source impedances of up to 100,000 ohms.

LESS THAN HALF AS WIDE as a standard 19-inch rack. Two Varian G-11A's mount side by side on a rack panel 10⅜ inches high. Or as a portable, the G-11A is an easy-to-handle 15 pounds. The G-10 sits on less than one square foot; its horizontal chart is handy for jotting notes.

MORE VERSATILE AND ADAPTABLE than any similar recorder — adjustable zero, adjustable span (from 9 to 100 mv on the G-11A), multiple chart speeds (up to four on the G-11A), and plug-in input chassis for different recording requirements.

PRICES THAT BEGIN AT $365 for the G-10 and $470 for the G-11A. Because unneeded performance costs money, Varian has intentionally designed for 1% limit of error and 1-second balancing time. Thus, Varian provides needed ruggedness, dependability and operating features at moderate cost.

VARIAN STRIP CHART RECORDERS



Varian G-11A for panel, rack or portable use for laboratory or equipment builder.

Varian G-10 bench-top recorder for accessible, horizontal chart.

WRITE TODAY FOR COMPLETE SPECIFICATIONS AND STANDARD OPTIONS

VARIAN associates

INSTRUMENT DIVISION

PALO ALTO 40, CALIFORNIA

CIRCLE 34 ON READER-SERVICE CARD

WHAT'S NEW

acteristics are about equal to those of hot-cathode tubes.

On the debit side, the new tubes do need a fairly high minimum voltage and some means for triggering the emission.

While it's still too early to predict what effect this development will have on the transistor industry, the chemical and physical stability of the cold cathode, as well as its wide temperature range, radiation resistance, and low cost, should make it a strong competitor for certain applications.

In addition to the audio output tube, which could be put in production now, other applications are in various stages of development. These include a high-gain preamplifier, a cold-cathode electron gun, a flat, picture-on-the-wall display device, and a new type of lamp for general illumination purposes.

Atomic Scale

. . . weighs freight cars on the move. It promises significant savings for the railroads.

CLEVELAND—

Last year American railroads spent almost $125 million weighing freight cars with track scales. Urgently pressed to cut costs, The New York Central, last month, experimented with a new technique that promises substantial savings in weighing. The new approach: a nuclear scale.

Research engineers from the Central tried out, in the Cleveland yards, a breadboard model of a device that uses gamma rays to measure the weight of freight-car shipments. The rays are emitted by a cobalt 60 source placed between the rails, and an amount depending on the thickness of the contents is absorbed by each car. The degree of penetration is measured by a scintillation counter suspended above the tracks.

Output of the counter is fed to an electronic computer, which records the weight of each car and transmits it to the railroad's car service bureau involved in the shipment.

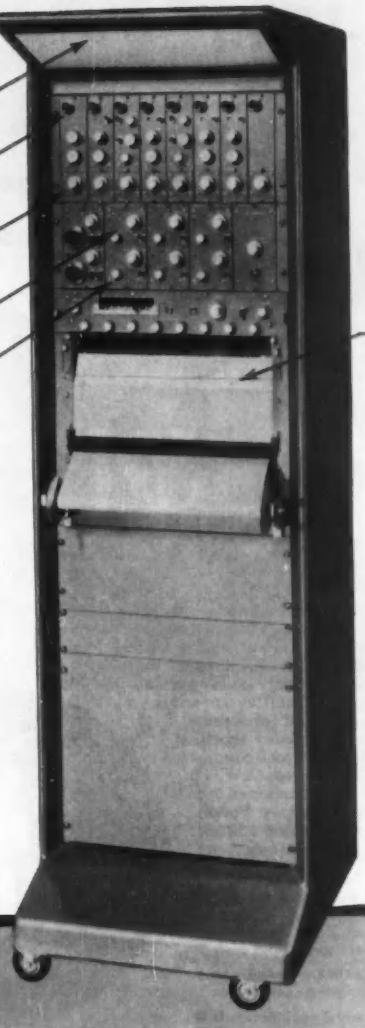
As a result of preliminary experiments, railroads see three advantages of the nuclear device:

- ▶ It will read weights while cars are in motion, moving at speeds up to 30 mph.
- ▶ It will weigh an entire series of cars in succession, cutting out uncoupling, which consumes a lot of time.
- ▶ Its cost is estimated at $25,000,

OFFNER
ALL TRANSISTOR

TYPE R DYNOGRAPH

the most versatile . . . most sensitive direct writing unit available



Illuminated canopy

Type 9800 series input couplers provide all input, control and balance functions. Input available both front and rear.

Type 481 Preamplifier provides sensitivities from one microvolt to 5 volts per mm.

Type 482 power amplifiers—may be used without preamplifiers for up to 10 mv/cm sensitivity

Zero suppression control

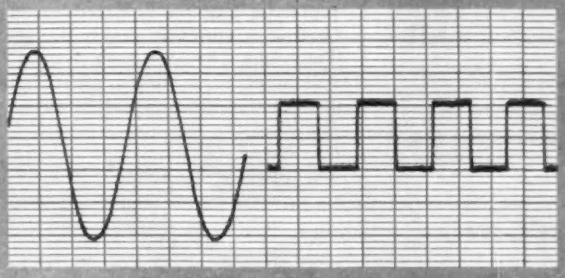
504-A paper drive—speeds from 1 to 250 mm/sec. Electrical speed shift 1 to 250 mm per minute available. Zero weave high precision drive, 850 ft. capacity (heat or electric) 1500 ft. (ink). Front loading, with full unobstructed record visible from front.

Combining all these features...

- *stable d-c sensitivity of one microvolt per mm*
- *true differential input*
- *high input impedance*
- *response to beyond 150 cps.*
- *reluctance, differential transformer, strain gage with a-c or d-c excitation, thermocouples, etc., used with all preamplifiers*
- *deflection time less than 1.5 milliseconds (2.5 ms with preamplifiers)*
- *fixed precision calibration*
- *instant warm-up*
- *precision source for d-c and 400 cycle excitation, self-contained*
- *zero suppression, twenty times full scale, both directions*

Thanks for your patience in awaiting deliveries of the Type R. Schedules were temporarily disrupted by the large volume of orders received for this radically new instrument. We are now in our new plant, with 300% more space, and are rapidly increasing production capacity. Deliveries will soon be on a current basis.

FULL SCALE, UNRETOUCHED CHARTS PRODUCED ON THE TYPE R DYNOGRAPH



EXTREME SENSITIVITY

10 Microvolt RMS Sine Wave — **Ten Microvolt D-C Square Wave**

Four recording media. Heat or electric rectilinear—ink or electric curvilinear. Readily convertible.

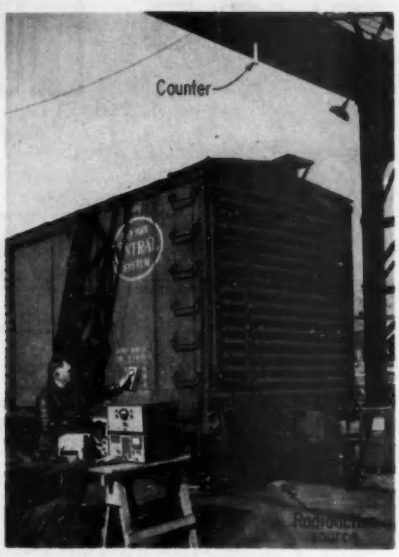
All these features . . . plus 8 channels in only 35" of rack space. Whatever your application for direct writing records . . . you should investigate the ability of the Offner Type R Dynograph to do the job *better* and more *simply*. Using transistor circuits* developed and tested for over three years in thousands of channels of Offner equipment, the Type R Dynograph has already proved its superiority in practically every respect to *any other* direct writing oscillograph. Write on your company letterhead for literature giving details and specifications.

**Patents granted and pending*

OFFNER ELECTRONICS INC.
3904 River Road, Schiller Park, Ill.
(Suburb of Chicago)

CIRCLE 37 ON READER-SERVICE CARD

WHAT'S NEW



Breadboard model of atomic scale gets a try-out in New York Central Railroad yards.

compared to $110,000 for an instrumented track scale currently used.

Says James T. Wright, director of the NYC Technical Research Center, "We are now convinced that atomic energy can do this job safely, economically, and accurately. The device will pose no radiation threat to workers or shipments. And the rays emitted will not be strong enough to damage a shipment, even one as sensitive as photographic film."

At present, the weighing device is accurate to plus or minus 1 percent of gross weight. That means it could be used to compile train tonnage figures. But better accuracy—within two-tenths of 1 percent—is required if the weights are to be used for billing purposes. Research Director Wright feels that future refinements will improve the accuracy of the gamma ray device to this point.

Next step is the development of a prototype unit for field testing. The Central is currently negotiating with Tracerlabs, Inc., for such a unit. It will have a series of sources and counters scanning the entire width of the cars (the breadboard model had only one of each). Researchers feel this will supply more accurate readings.

—William Meldrum
McGraw-Hill News

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Two new computers have been developed by the Czechoslovakian Research Institute for Mathematical Machines. One will solve partial differential equations; the other is an interpolator for machine tool control.

An Editor Looks at The Physical Society Show

CtE's Derek Barlow spotted some new instrument developments as he made the rounds at Britain's annual Physical Society Exhibition.

LONDON—

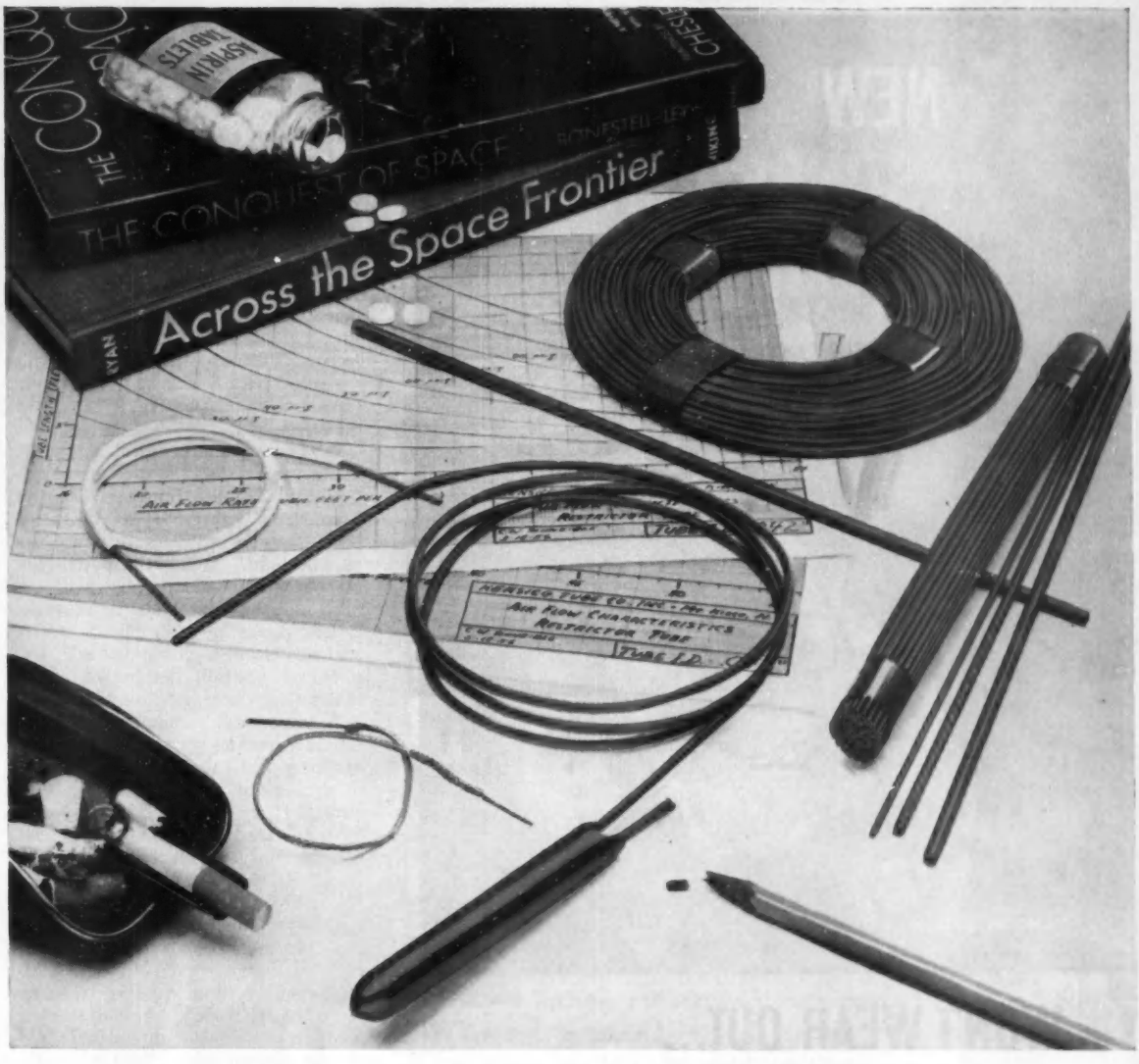
British scientists have often been accused of producing new ideas and then leaving the development to others. At January's Physical Society Exhibition, visitors saw ample evidence that there was still no drought of ideas. But how far along these innovations would come was anyone's guess. Here are a few of the most outstanding ones:

▶**High precision, brushless tachogenerator** designed for speeds as low as a few revolutions per hour. Invented by Prof. F. C. Williams of Manchester University, the instrument measures speed of rotation of a conducting surface by observing the magnetic field produced by circulating currents induced in the rotating member.

On the input shaft a nonferrous squirrel-cage rotor is mounted, located between the poles of a primary magnet. As the rotor revolves, circulating currents generate a field perpendicular to the primary field. The field is detected by a second harmonic-type flux detector made of two high-permeability strips carrying opposing windings energized from a frequency source. When both strips are energized by the perpendicular field, a third winding takes off an output proportional to the speed and direction of the rotor. An experimental prototype measures speeds as low as 0.1 rpm.

▶**A simple contact system** operated from the normal centrifugal governor eliminates speed-hunting on small electric motors. A stud with an oblique surface face protrudes from the governor system. Movement of the governor weights advance or retard the pin along its axis. Motion of the pin makes and breaks contacts in series with the motor, so that the time of application of the driving voltage in each and every revolution is proportional to the deviation of motor speed from its set value. Compared with simple governor control, speed variations are cut by 60 percent.

▶**New induction digitizer** developed by GEC of Coventry provides five-digit cyclic binary-coded decimal outputs without sliprings, photocells, or



INNER SPACE PROBLEMS?

Most control engineers know they can rely on Kensico copper tubing to help solve problems of *inner space* control. Kensico's highly skilled workmanship produces *precision-drawn, trouble-free* Capillary and Restrictor tubes for instrumentation and control systems. Mirror-smooth inside surfaces. Dependable, uniform flow.

No flaking. Exact specifications. Accurate flow testing. Overall tube cleanliness. Friendly service. Engineering consultation available. Write for Free Flow Charts today.

We also make hard and soft copper water tube . . . copper air conditioning and refrigeration tubes . . . copper tubing for propane gas lines, heat exchangers, automotive and industrial applications.

CAMBRIDGE, MASS. • BUFFALO, N. Y. • LINDENHURST, N. Y. GOSHEN, N. Y. • ROSELLE, N. J. • PHILADELPHIA, PA. • PITTSBURGH, PA. • CLEVELAND, OHIO • DETROIT, MICH. • EVANSTON, ILL. ST. LOUIS, MO. • DURHAM, N. C. • FT. LAUDERDALE, FLA. ST. PETERSBURG, FLA.

Kensico Tube

COMPANY INCORPORATED, MT. KISCO, N. Y.

CIRCLE 41 ON READER-SERVICE CARD

commutators in the volume of a size 11 synchro. It consists of a transformer with a single exciting winding and a number of secondary windings equal to the number of digits. A moving yoke decides the polarity of coupling between the exciting winding and the various digit windings which are arranged according to the code used.

Adaptation of the same principle is being tried where the core and windings of the transformer are opened into the arc of a meter scale. A light magnetic yoke is attached to the conventional meter-pointer to give the digital readout.

▶**The only mechanical analog-to-digital converter,** according to its builder, CNS Instruments, Ltd., of London, uses a normal self-balancing potentiometer on which is mounted a pinwheel disc. When the potentiometer balances and the disc with its protruding pins is locked in position, a cam drives an assembly of microswitches against the pinwheel. The pinwheel position determines which switches are energized for a binary output. Using only standard parts, CNS claims a reading speed for three digit numbers of 10 sec per channel. Cost of a 50-input system complete with electric typewriter: $4,200.

▶**Moire fringe positioning systems** may become simpler following a development at the National Physical Laboratory that overcomes troubles caused by phototransistor temperatures. In the system—still in its prototype stage—light passes through a 75-line-per-inch drum grating rotating at constant speed. A half-silvered prism transmits the modulated light in two perpendicular directions. One beam passes through a fixed grating on a phototransistor; the other illuminates a second phototransistor through a grating attached to the moving worktable.

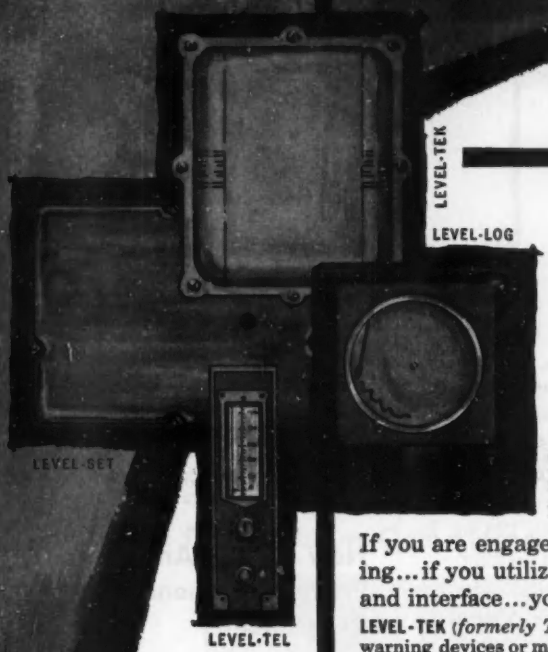
Previous methods have provided only a single pulse per fringe; the new NPL system allows continuous interpolation between fringes with an accuracy of 0.0002 in.—and requires only half as many phototransistors.

▶**Moire fringe techniques** also appear in an automatic burette monitor developed by the United Kingdom Atomic Energy Authority. A collar containing a light source and phototransistor surrounds the burette. Mounted parallel to the burette are a pair of 100-lines-per-inch diffraction gratings. As the collar moves down the burette the phototransistor counts the moire fringes generated.

In operation, an electric motor hoists the collar up until it reaches a

CIRCLE 43 ON READER-SERVICE CARD →

IMPORTANT ANNOUNCEMENT



New family name for Robertshaw level measurement and control instruments

On January 1, 1959, Robertshaw adopted more uniform and meaningful trade names to identify its line of capacitance instruments.

If you are engaged in mining, refining, processing or manufacturing...if you utilize or encounter liquids, granular solids, powders and interface...you can rely on these time-tested products.

LEVEL-TEK *(formerly Tektor)* — An on-off device which operates local or remote warning devices or motor-driven valves and pumps when a predetermined level has been reached.

LEVEL-TEL *(formerly Telstor)* — A continuous level system which detects, measures and visually indicates changes in media level.

LEVEL-SET *(formerly Pneutronic Level Controller)* — An instrument which converts changes in level to proportional changes in air pressure for maintaining a constant head in vessels where pneumatic feed control systems are employed.

LEVEL-LOG *(formerly Series 42 Recorder-Controller-Indicator)* — A versatile and extremely accurate RF null balance capacitance system for level measurement, recording and control.

AERONAUTICAL AND INSTRUMENT DIVISION

Robertshaw-Fulton CONTROLS COMPANY

SANTA ANA FREEWAY AT EUCLID AVENUE • ANAHEIM, CALIFORNIA

stop mechanism at the top of the burette. The collar remains there until released. Then it falls under the influence of gravity, registering the distance of fall in multiples of 0.01 in. When the liquid meniscus is reached, the light beam is interrupted and counting ceases. Meniscus height is printed out on paper tape.

—Derek H. Barlow

Panellit to Evaluate British Computers

Four of the new British National-Elliott 802 computers will shortly be on their way to the United States to Panellit, Inc., for trials and eventual inclusion in Panellit's industrial data processing systems.

The 802, developed by Elliott Brothers (London) Ltd.—a member of the Elliott-Automation Group, the British subsidiary of Panellit—is a fully-transistorized machine designed for either office-data processing or as a part of the Panellit 609 information system. Both input and output to the 802 is supplied on five-hole punched tape; input speeds: 170 characters per sec; output rate: 25 characters per sec. A magnetic core storage has a capacity of 1,020 words, each of 33 binary digits.

First British installation of the 802 will be made shortly at the Calder Hall nuclear power station. Its use: reactor temperature monitoring.

New Process Analyzer Provides Response Diagrams

Based on analog computer and gated integration techniques, a new process response analyser developed by the Solartron Electronic Group of England produces phase-amplitude response diagrams down to a frequency of one cycle in 10^4 sec with an accuracy of 1.5 percent. Upper-frequency limit of the system is said to be 1,000 cps.

There are two basic units, the oscillator and the display cabinet. The oscillator provides four-phase sine-wave, square-wave or triangular outputs. Meters on the display cabinet register amplitude and sign of the real and imaginary components of the system output signal. Digital readout connections enable the system to be used for automatic X and Y plotting of Nyquist diagrams.

KOLLMORGEN Remote Viewing Systems...
used in most atomic installations

Photo courtesy Phillips Petroleum Company

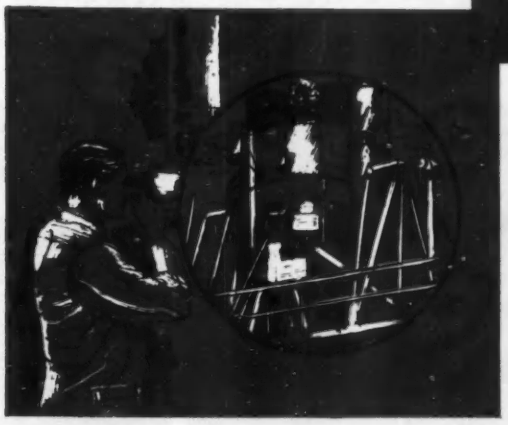
A Phillips Petroleum Company technician observes radioactive metallurgical specimens through a Kollmorgen Hot Cell Periscope installed at the Materials Testing Reactor Hot Cell, National Reactor Testing Station. The periscope helps determine characteristics such as tensile and impact strength, hardness, weight and density changes. Macrophotography of specimens is also performed through the periscope.

Radioactivity, caustic fumes, blast forces, inaccessibility and other adverse conditions hamper observation and inspection. To overcome these conditions, more and more installations in a widening range of industries are using Kollmorgen remote viewing instruments. Kollmorgen specializes in the design and manufacture of instruments and systems for detailed observation under difficult or apparently impossible circumstances. Most of these devices can be readily adapted to photography or television.

We have recently prepared a twenty-four page illustrated brochure which describes our facilities and primary fields of interest. For a copy, please write to Department 213.

The Nautilus and her sister ships of the Atomic Fleet, like most other U.S. submarines, are equipped with Kollmorgen periscopes. These instruments require highly precise optical, mechanical and electronic components.

and from Cape Canaveral to the



Kollmorgen Bunkerscopes are used at Cape Canaveral for observation of missile launching operations and static tests. Bunkerscopes allow detailed observation from a considerable distance with no danger to the operator. Images appear in bright, clear, natural color. There are no maintenance costs with these Bunkerscope operations.

Kollmorgen will exhibit at the Atomfair, Cleveland, April 5-10. Booth 501.

K O C **KOLLMORGEN**
optical corporation
NORTHAMPTON, MASSACHUSETTS

CIRCLE 45 ON READER-SERVICE CARD

AROUND THE BUSINESS LOOP

Smith Finds a Parent

And Allis-Chalmers gets a new Hydraulic Div. by purchasing the Pennsylvania valve and turbine maker that had been three years looking for an acquiring firm.

Though it remained financially strong, Allis-Chalmers Mfg. Co., sustained a few direct hits in the recession. Highpoint of the year-long trek back up the sales curve came on Jan. 28, when the big, diversified manufacturer purchased the much smaller (1,000 employees) S. Morgan Smith Co. of York, Pa., the all-muscle-no-fat designer and builder of hydraulic turbines, valves, and other machinery.

More than 430,000 shares of Allis-Chalmers common stock were exchanged at a 1.1 to 1 ratio for more than 395,000 capital shares of SMS stock, of which three-fourths is held by the Smith family. At current values, the A-C stock would be worth about $12 million. It represented a new issue, did not necessitate an increase in authorized amount.

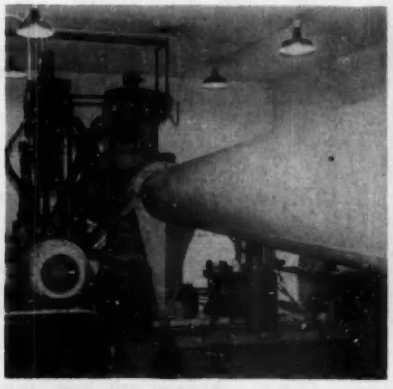
The affiliation is a beautiful illustration of mutual respect. Important companies, some of them as large as Allis-Chalmers, had courted S. Morgan Smith ever since it announced, about three years ago, that it was seeking an acquiring firm. Its stipulations: the firm had to be able to make good use of SMS's facilities, and at the same time show sufficient diversification and potential earning power to make an exchange of stock taste sweet to its stockholders. The choice of Allis-Chalmers reflects, therefore, a high degree of invested confidence.

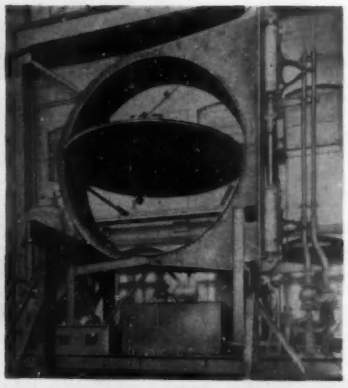
• **Industry leaders**—The two companies have been among the four foremost manufacturers of water-power-generation equipment in the U.S. (the others are Baldwin-Lima-Hamilton Corp. and Newport News Shipbuilding & Dry Dock Co.). The merger simply takes SMS out of the running as a separate company, shapes it into the new Hydraulic Div. of A-C's Industries Group. It does not affect the autonomy of SMS's engineers.

Stephen Morgan Smith, who developed one of the first successful hydraulic turbines in the U.S., formed his company in 1877. It was destined to become a leading designer and builder of these turbines, and a producer of control valves and other components for many industries.

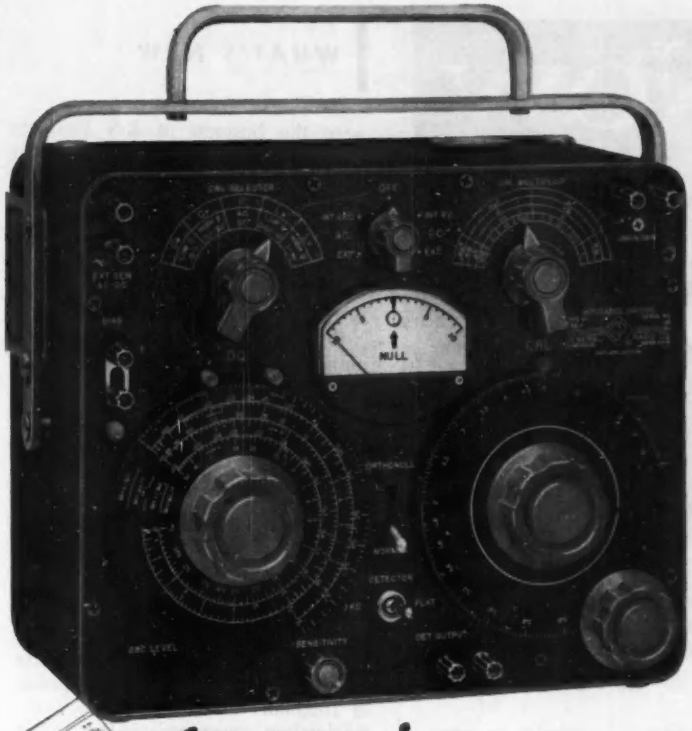
• **Valves are big business**—Conical plug-type Rotovalves and butterfly valves ranging in size from 4 in. to a gigantic 72 in. account today for about 25 percent of SMS's annual billings. These products have gone into, among other things, aircraft windtunnels. The photos on this page show an 18-ft-in-diameter butterfly valve designed by SMS for the world's largest propulsion windtunnel at Tullahoma, Tenn., and a 24-in. Rotovalve it built and installed between the blowdown vessels and settling chamber in a 3,700-mph windtunnel at Convair-San Diego. New models are being designed for 2,500 psi at 2,500 deg F.

The butterfly valves, incidentally,





Left—This 18-in.-in-diameter butterfly valve was designed by S. Morgan Smith for the plenum evacuation system of the world's largest propulsion windtunnel at Tullahoma, Tenn. The big valve moves from full open to full closed in about 10 sec, supplies 1,200 psi oil pressure to the operating cylinders. Right—This 24-in. Rotovalve, designed for Convair—San Diego, operates at 600 psi, 400 deg. F, on a 1-sec open-to-close cycle. Its rangeability is about 150 to one.



RUGGED
PORTABLE PACKAGE

Announcing . . . A NEW IMPEDANCE BRIDGE

A Completely New Design to Replace A Famous G-R "Workhorse"

. . . provides protection in transit and convenience in use

- ★ Bridge is battery operated and completely self contained — has built-in transistorized 1-kc oscillator and selective detector; meter null indication for both ac and dc. Total battery drain is less than 10 ma, providing 1-yr. life for typical laboratory use.
- ★ Orthonull*—a new, unique mechanical ganging of bridge's variable elements permits measurements to be made *without annoying sliding balances.*
- ★ Wide range — to 1000 μf, 1000 h, and 10 MΩ.
- ★ Accuracy holds over all ranges — not reduced at range extremes.
- ★ Provision for applying up to 600v dc to capacitors and small currents to inductors for polarization purposes and measurements at various d-c levels.

. . . panel tilts to any convenient angle

PARAMETER	RANGE	ACCURACY
Resistance, AC and DC (External DC required above 100 kΩ)	0.001 Ω to 10 MΩ 8 ranges	±1% ± 0.001 Ω (residual R ≤ 1 mΩ)
Capacitance, series or parallel	1 μμf to 1000 μf 7 ranges	±1% ± 1 μμf (residual C ≤ 0.5 μμf)
Inductance, series or parallel	1 μh to 1000 h 7 ranges	±1% ± 1 μh (residual L ≤ 0.2 μh)
D (for series capacitance case)	0.001 to 1 at 1 kc	±5% ± 0.001 at 1 kc
D (for parallel capacitance case)	0.1 to 50 at 1 kc	±5%
Q (for series inductance case)	0.02 to 10 at 1 kc	±5%
Q (for parallel inductance case)	1 to 1000 at 1 kc	for 1/Q ±5% ± 0.001 at 1 kc

FREQUENCY RANGE: (1-kc supplied internally)
1% accuracy for L and C from 20c to 20 kc
1% accuracy for R from 20c to 5 kc
D and Q ranges are direct reading at 1kc

Type 1650-A Impedance Bridge . . . $440.

Type 1650-P1 Test Jig, for convenient production testing . . . $19.00.

SEE IT AT THE IRE SHOW
along with 15 other important new instruments
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*U.S. Patent 2,872,639

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The Best Instruments In Electronics

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CIRCLE 47 ON READER-SERVICE CARD

were the business of R-S Products Corp. of Philadelphia, whose common stock was acquired by purchase in 1950. R-S Products was operated as a subsidiary until 1953, when it was merged into SMS and became part of the parent company's Valve Div. In 1957, this operation was transferred to the home office at York.

Other SMS lines are water-handling equipment, adjustable- and fixed-vane axial-flow pumps, axial-flow air compressors, and specially-designed hydraulic and mechanical equipment.

Still its most important products, SMS's hydraulic turbines today are developed to the point where different units can handle water heads of from less than 100 ft to more than 1,000 ft. Some, like the six reversible units being built for the Tuscarora Pump Power Plant at Niagara, N. Y., have extreme capabilities. These turbines can pump water as well as generate power, and have a total horsepower of 168,000.

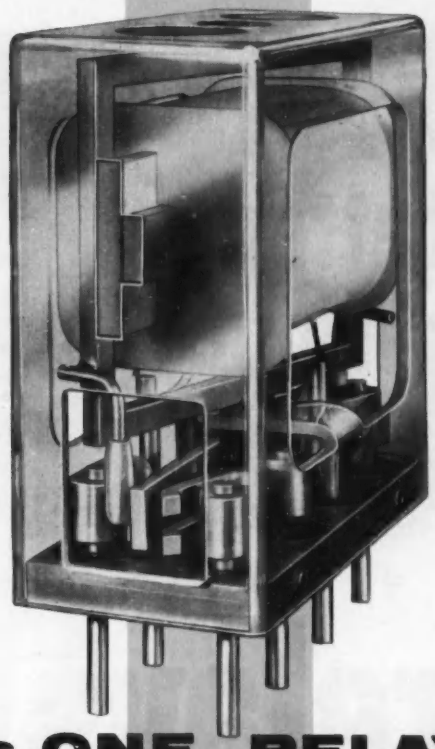
• **Joined on power project**—It is at this new Niagara power project that the mutuality of S. Morgan Smith's and Allis-Chalmer's interests comes into perhaps clearest focus. While the newest AC facility works on one portion of the project, on a plateau about a mile east of the Niagara River, another (West Allis) works on the Lewiston (N. Y.) Power Plant, located on an escarpment of the Niagara River about three miles below Niagara Falls.

In 1890, S. Morgan Smith employed 20 people and had a limited outlet for its products. Today, its 1,000-plus employees work in 447,000 square feet of space, divided into two plant sites. In 1957, a record year for the Pennsylvania company, sales totaled $23,495,542, and net earnings came to $1,563,797. Backlog, as the company went into 1958, amounted to $31,649,218.

• **A-C also healthy**—The firm that was founded in Milwaukee in 1847 to manufacture French burr millstones for flour milling, became known as Allis-Chalmers in 1901, when it added mining and ore-processing machining to its burgeoning product line. For it, too, 1957 (the last full year for which figures have been disclosed) was a good year. Sales came to $534,146,000, down by only about 2.4 percent from a record $547,439,000, while earnings were $17,819,251, down by about 9.3 percent from a previous $20,355,045.

Furthermore, Allis-Chalmers officials believe that though sales for

CIRCLE 47 ON READER-SERVICE CARD



4 times actual size

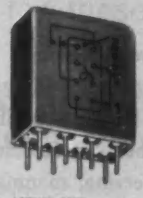
Mock-up of CLARE Type F Relay enlarged to show operating mechanism. Note bifurcated contacts which enable this relay to handle a wide variety of contact loads.

With this ONE RELAY

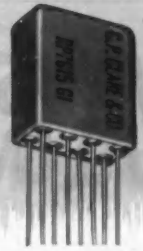
You can handle contact loads from 3 amperes down to 1 microampere, 1 millivolt

SPECIFICATIONS

Ambient Temperature	—65° C to +125° C.
Shock	65 Gs for 11 milliseconds.
Vibration	5-75 cps at maximum excursion of ¼ inch, 75-2000 cps at 20 Gs acceleration.
Dielectric Strength	Sea level—1000 volts rms between terminals and frame, and between adjacent circuits; 750 volts rms between contacts of a set. At 80,000 ft., 350 volts rms.
Insulation Resistance	1000 megohms minimum at 125° C.
Coils	Coils up to 10,000 ohms available for a wide range of voltage or current operation.
Nominal Operating Power	250 milliwatts.
Pickup Time	3.5 milliseconds nominal.
Dropout Time	1.5 milliseconds nominal.
Contact Arrangement	2 pdt (2 form C).
Contact Rating	3 amps resistive at 28 volts d-c or 115 volts a-c; also will handle loads of 1 microampere @ 1 millivolt reliably.
Contact Resistance	0.30 ohm maximum.
Contact Life	500,000 operations minimum at 2 amps; 100,000 operations minimum at 3 amps; 1,000,000 operations minimum at 1 amp.
Enclosure	Hermetically sealed, filled with dry nitrogen at 1 atmosphere pressure.
Mounting	All popular mounting arrangements available.
Terminals	Printed circuit; solder; plug-in (matching socket available). Variations of printed-circuit terminal length on 1/10-inch grid spacing available.
Weight	17 grams.
Military Specifications	MIL-R-25018, except as to contact bounce.



ACTUAL SIZE
All popular mounting arrangements are available. Terminal arrangements nicely suited to 1/10 inch grid spacing.



• In one relay—the Type F—CLARE provides a precise component of unusual flexibility for long life operation under a wide variety of contact loads.

Tests have shown a performance of over 22,500,000 operations at 0.1 ampere, 115 volts a-c. Minimum contact life at 3 amperes is 100,000 operations. Contacts have carried 1 microampere, 1 millivolt for 700,000 operations with a failure resistance of 500 ohms, with no misses recorded.

This amazing low-level life is primarily a result of the use of gold plated contacts. These same contacts, however, will carry up to 3 amperes.

A special plug-in mounting arrangement that will stand extreme shock and vibration is now available.

The CLARE Type F Relay is hermetically sealed, operates perfectly in a wide range of temperatures, withstands heavy shock and vibration—is fast and more than moderately sensitive.

Send for Engineering Bulletin No. 124

Write or call C. P. Clare & Co., 3101 Pratt Blvd., Chicago 45, Illinois. In Canada: C. P. Clare Canada Ltd., 2700 Jane Street, Toronto 15. Cable Address: CLARELAY.

CLARE RELAYS

FIRST in the industrial field

CIRCLE 49 ON READER-SERVICE CARD

WHAT'S NEW

1958 may total up a little below those for 1957, the profit margin should be better. They point to an improvement in sales in the last six months of last year, which did not quite reach a high-enough level to overcome a slow start.

Products for the control field glitter under A-C's tremendous expanse (16 plants in the U.S., Canada, and England). The Industries Group, for example, produces machinery for the generation, distribution, transmission, and control of electric power. Like S. Morgan Smith, it fills major orders in the hydroelectric field; but it also furnishes condensers and betatrons, does outstanding work in insulation, and has trained more than 10,000 persons in its Mobile Regulator Engineering Training School.

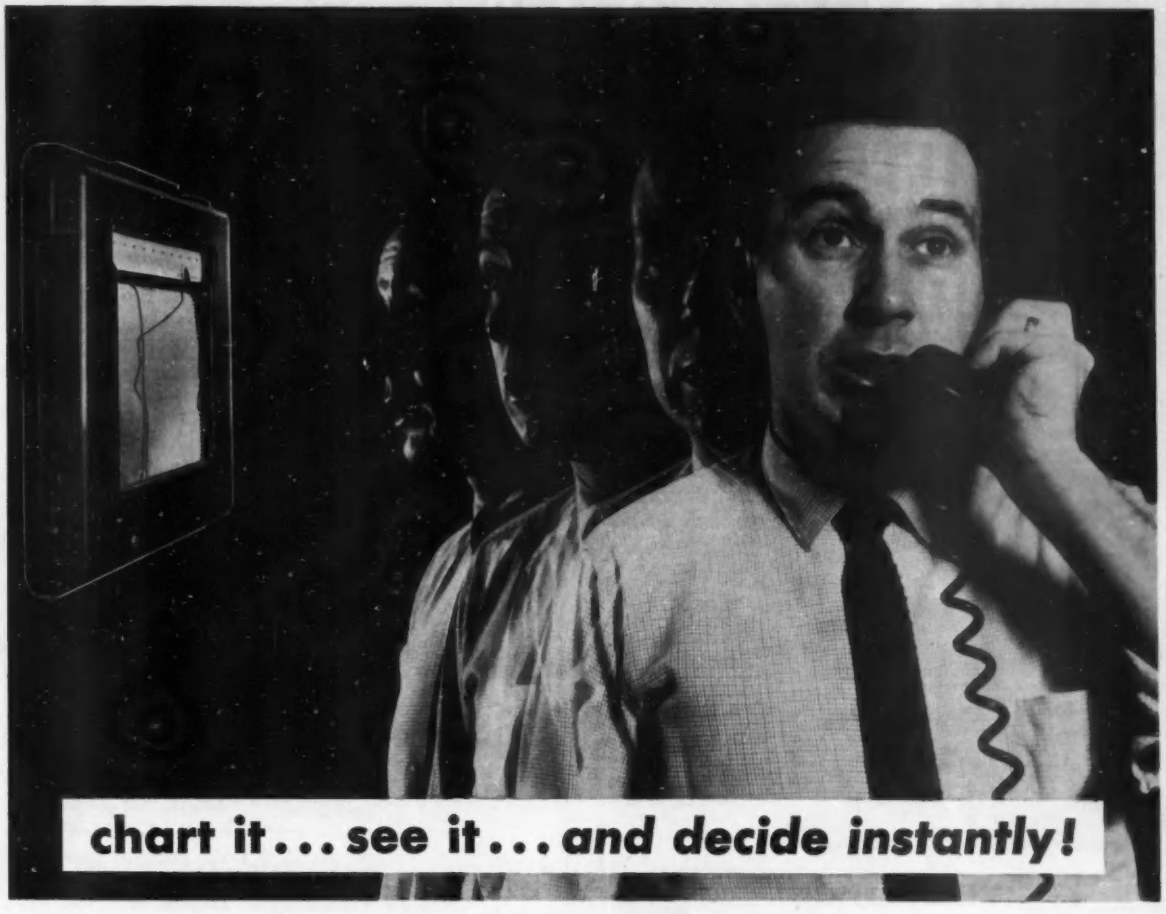
The Industrial Equipment Div. manufactures compressors, induction and dielectric heating equipment, rectifiers, crushers, grinding mills, rotary kilns, screens, roller mills, and other processing machinery, as well as complete processing plants. The introduction of semiconductor diode equipment has shot this division's rectifier sales skyward. In 1957, it received its largest order in 10 years for mercury arc rectifiers.

• **The key men**—Allis-Chalmers: R. S. Stevenson, president; W. G. Schell, executive vice-president; Joseph L. Singleton, vice-president, Industries Group; J. W. McMullen, vice-president and general manager, Power Equipment Div.; W. M. Wallace, vice-president and general manager, General Products Div.; P. R. Bauer, vice-president and managing director, A-C International; H. K. Ihrig, vice-president, Research Div.; J. D. Greensward, vice-president and general manager of manufacturing, Industries Group; R. M. Casper, general manager, Atomic Energy Div.; R. L. Halsted, general manager, Industrial Equipment Div.

Hydraulics Div. (formerly S. Morgan Smith): Beauchamp E. Smith, general manager; Burwell B. Smith, assistant general manager for sales; Duncan D. McArthur, assistant general manager for industrial relations, procurement, and the comptroller's office. William J. Rheingans will be in charge of engineering.

TI, Metals & Controls Talk Merger; Others Tie Knot

Still in the talking stage is a merger that would consolidate Texas Instrument, Inc., of Dallas and Houston,



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Rocket "go or no-go" charts . . . whatever chart design you need, call us . . . we'll modify, or start from scratch to fit your needs exactly . . . send for "Special" data!

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CIRCLE 51 ON READER-SERVICE CARD

WHAT'S NEW

and Metals & Controls Corp. of Attleboro, Mass., into a $135-million-a-year enterprise (TI's sales for 1958: more than $90 million; Metals & Controls': $45 million). One preliminary of the merger has already been accomplished: C. J. Thomsen, formerly director and vice-president of TI, has been elected president of M&C, and is now active in that office.

An exchange of stock will consummate the merger, if and when it comes off. Stockholders will vote on it early this year.

But other mergers are already facts. They involve:

▶ Eastern Air Devices, Inc., and Norbute Corp., the industrial subsidiary of Crescent Petroleum Corp. Explained W. H. Garbade, president of Crescent Petroleum: "In line with our development in oil and gas, we are striving for parallel growth in our chosen field of industrial activities—scientific and laboratory installations, electronic and electrical manufacturing. We have just achieved a major step in this direction through the acquisition of Eastern Air Devices, Inc., a well-known manufacturer of specialized electronic-mechanical equipment." Hugh G. Hamilton, president of EAD, becomes president of the new EAD Div.

▶ Combustion Engineering, Inc., and General Nuclear Engineering Corp. Actually an acquisition, with Combustion Engineering in the ascendant role, this move puts General Nuclear's President Walter Zin in charge of all of Combustion's nuclear power activities. Some of these activities: fuel element fabrication, core assembly, and the manufacture of a variety of heavy components. Zinn is a former director of the AEC's Argonne National Laboratory.

▶ Amphenol Electronics Corp. and The George W. Borg Corp. Stockholder approval cements this merger, initiated earlier by the two managements (CtE, Jan., p. 152).

Now It's—

Northrop Corp. and the **Norair Div.**; formerly Northrop Aircraft, Inc., and the Northrop Div.

Airpax Electronics, Inc.; formerly the Airpax Products Co.

Airdox Cardox Products Co. of Chicago (gas compression systems); formerly Cardox Corp.

The **Controls Div.**, formerly the Mechanical Div., of Hagan Chemicals & Controls, Inc.

LAMBDA'S ALL-TRANSISTOR LINE

Delivered now • Guaranteed for five years

FOUR NEW POWER SUPPLIES

1-AMP and 2-AMP · CONVECTION COOLED

No internal blowers • No moving parts

0-32 VDC

0-1 AMP 0-2 AMP

Model LT 1095	$285
Model LT 1095M (metered)	$315
Model LT 2095	$365
Model LT 2095M (metered)	$395

- **Ambient 50° C at full rating.**
- **High efficiency radiator heat sinks.**
- Silicon rectifier.
- 50-400 cycles input.
- Special, high-purity foil, long-life electrolytics.
- **Compact. Only 3½" panel height.**
- **Short-circuit proof.**
- Protected by magnetic circuit breakers.
- Hermetically-sealed transformer. Designed to MIL-T27A.
- **All transistor. No tubes.**
- **Fast transient response.**
- Excess ambient thermal protection.
- Excellent regulation. Low output impedance. Low ripple.
- Remote sensing and DC vernier.

CONDENSED DATA

Voltage Bands . . . 0-8, 8-16, 16-24, 24-32 VDC

Line Regulation . . . Better than 0.15 per cent or 20 millivolts (whichever is greater). For input variations from 105-125 VAC.

Load Regulation . . . Better than 0.15 per cent or 20 millivolts (whichever is greater). For load variations from 0 to full load.

AC Input . . . . . 105-125 VAC, 50-400 CPS

Electrical Overload Protection . . . Magnetic circuit breaker, front panel mounted. Unit cannot be injured by short circuit or overload.

Thermal Overload Protection . . . Thermostat, manual reset, rear of chassis. Thermal overload indicator light, front panel.

Size . . . . . 3½" H x 19" W x 14⅜" D.

Send for your copy.

New! **1959 CATALOG NOW AVAILABLE**

New 36-page edition contains information and specifications on Lambda's full line of transistor-regulated and tube-regulated power supplies.

LAMBDA ELECTRONICS CORP.

11-11 131 Street, College Point 56, N.Y.

CIRCLE 53 ON READER-SERVICE CARD

WHAT'S NEW

Is TEAM in a Slump?

Hoffman has confined unique subcontracting approach to one effort, has handled subsequent jobs in a conventional way. Why, is hard to say.

Two things were especially interesting about the Tall Tom all-electronic reconnaissance system that Hoffman Electronics Corp. was building for the Air Research & Development Command of the Air Force (CtE, April '58, p. 42): it was the biggest contract Hoffman, a relatively small control firm, had ever received, and it was going to be handled on the TEAM (Total Engineering and Administrative Management) level.

But that was almost a year ago. No more Hoffman contracts have become TEAM projects, and one has superseded Tall Tom as Hoffman's largest.

Two questions immediately suggest themselves: what has been the progress of Tall Tom, the one TEAM contract, and why hasn't a contract for the Air Materiel Command, which superseded Tall Tom in size, been undertaken as a TEAM job?
are some of the other contracts received by Hoffman to-date?

• **Too top-secret**—Hoffman's feeling is that a full disclosure of how TEAM now shapes up in the eyes of top officials will be giving away too much about Tall Tom itself, which is an extremely classified project. For this reason, it prefers to speak only in very general terms about its unique contract-engineering approach. Here is all it will say:

The TEAM concept has worked out very satisfactorily, with only slight modifications made to the organizational structure as first proposed to the Air Force. Under the concept, the Hoffman Laboratories Div. at Los Angeles, guided by a management policy board of key representatives of participating companies, acts as systems manager. It assigns a program director, who has responsibility for the overall performance of a contract, and three assistant directors, who report to him on: systems engineering, fiscal, purchasing, and contract operations, and communications.

The outstanding feature of TEAM, Hoffman has said, is that it provides the necessary degree of intimacy between a prime contractor and its subs. The economics that are obtained result because all subcontractors are

(*Continued on page 177*)

ALLIS-CHALMERS ACQUIRES S. MORGAN SMITH ...FORMS NEW HYDRAULIC DIVISION

On February 1, the S. Morgan Smith Company became a part of Allis-Chalmers. Extensive A-C facilities in Milwaukee, together with two S. Morgan Smith plants in York, Pennsylvania, are now operating as the newly created Allis-Chalmers Hydraulic Division.

In acquiring S. Morgan Smith, A-C combines its own broad background in hydraulics with the 80 years of diversified engineering and manufacturing knowledge of SMS.

The York facilities will be devoted to the continued research, design, engineering and fabrication of a complete line of hydraulic turbines and accessories, pumps and pump-turbines, valves for industrial, waterworks and power applications, and specialized heavy equipment.

Product information or engineering help can be obtained from your nearby Allis-Chalmers office, or by writing Allis-Chalmers, Hydraulic Division, York, Pennsylvania.

HYDRAULIC DIVISION

RESEARCH · DESIGN
HYDRODYNAMICS
ENGINEERING · FABRICATION

Rotovalves • Ball Valves • R-S Butterfly Valves • Free-Discharge Valves • Liquid Heaters • Pumps • Hydraulic Turbines & Accessories

ALLIS-CHALMERS

CIRCLE 55 ON READER-SERVICE CARD

ATLAS

The myth and the missile

THE MYTH: Because he warred with Zeus, Atlas, in classical mythology, was punished by being made to support the entire world on his shoulders.

THE MISSILE: Today's Atlas ICBM bears a symbolic relationship to its classical namesake. For the future course of world events may well depend in large part on the role of the mighty Atlas. ***ARMA*** provides the guiding spirit for the Atlas: the inertial navigation system which guides it to its destination. Brain of the system is ***ARMA***'s airborne digital computer, operational under severest conditions of vibration, temperature, noise, acceleration and deceleration. Heart of the system is ***ARMA***'s inertial platform, the stable reference table from which data is fed to the computer.

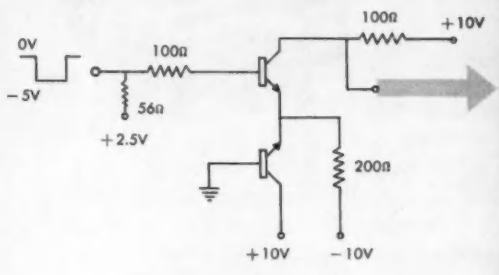
ARMA also provides a comparable all-inertial guidance system for the Titan ICBM, companion-in-arms of the Atlas. ***ARMA*** . . . Garden City, New York. A Division of American Bosch Arma Corporation. 6416

AMERICAN BOSCH ARMA CORPORATION

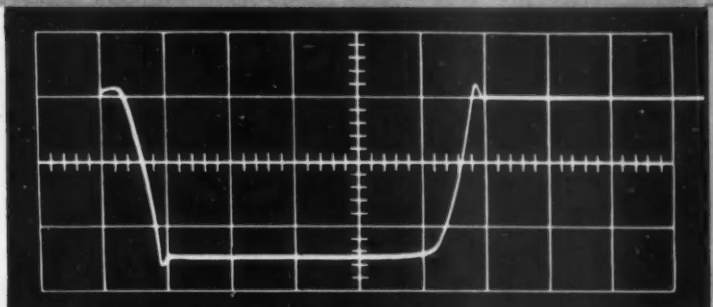
6416

NEW SILICON TRANSISTORS

FOR FAST POWER SWITCHING



SWITCHING TEST CIRCUIT



50 ma pulse .2μsec/cm on Tektronix 541 Oscilloscope

Featuring fast switching, low capacitance, and good bottoming voltage in the range of 10 to 100 milliamps, Transitron's 2N1140 extends what is already industry's widest range of silicon switching transistors. The 2N1140 is designed for use as a drum memory driver, core driver-driver, and high level multivibrator.

Additional new types ST4080 and ST4081, because of their Beta linearity and superior bottoming, offer many advantages over types 2N339, 2N342 and 2N343.

For further information, write for Bulletin *TE-1355*.

ABSOLUTE MAXIMUM RATINGS

	2N1140	ST4080	ST4081	2N339	2N342	2N343
V_{ce}	40	60	60	55	60	60 Volts
V_{eb}	5	3	3	1	1	1 Volts
Power Dissipation 100°C amb.	0.5	0.5	0.5	0.4	0.4	0.4 Watts
100°C case	1.2	1.2	1.2			Watts

SPECIFICATIONS AND TYPICAL CHARACTERISTICS AT 25°C

h_{fe} at IKc I_c = 10 ma, V_c = 10 Volts	50	20-50	30-90	9-90*	9-32*	29-90*
I_{co} at Max. rated voltage	15	25	25	50	50	50 μa
Max R_{cs} at I_c = 20 ma, I_c = 5 ma	50**	100	100	300	350	350 ohm
h_{fe} at 10 mc typical	5					
C_c at V_{cb} = 10 volts, I_e = 0	16					μμf.
h_{fe} at I_c = 50 ma, V_{ce} = 6V	50					
Rise time	.13					μsec.
Fall time	.10					μsec.

*at I_c = 5 ma, V_c = 10 Volts

**at I_c = 50 ma, I_b = 5 ma

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1649 TIMERS

that **SOLVED** special control problems.

• How this engineering experience can help you.

The small Time Delay Timer represents one of the simplest motor driven timers we manufacture. It is a reliable standard fixed time delay type.

Industrial Timer also manufactures this Punched Tape Programmer which controls 85 individual load circuits through an unlimited number of steps. No coding or elaborate memory systems are required, making possible direct control from Programmer to process.

Between these two extremes we list 1688 different timers, of which 39 are standard types and 1649 are "specials" developed to solve difficult control problems.

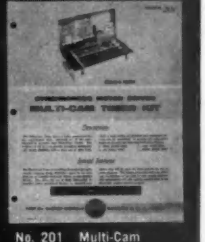
Most timing problems have their own unique characteristics. However, it very often happens that a control problem is quickly solved by one of these 1649 already developed special timers. If not, we have the staff, the experience (20 years) and what's more important, the desire to design and deliver the timer that fills your needs 100%. Send us your specifications.

COMPLETE NEW TECHNICAL BULLETINS NOW READY
Ask for complete catalog or individual bulletins by number

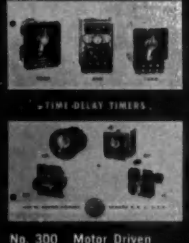
Complete Catalog Timing Controls

No. 100 Card & Tape Programmers

No. 200 Motor Driven Cam Timers



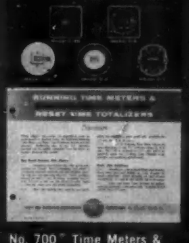
No. 201 Multi-Cam Timer Kit



No. 300 Motor Driven Time Delay Timers

No. 400 Motor Driven Interval Timers

No. 500 Motor Driven Recycling Timers



No. 700 Time Meters & Time Totalizers

No. 800 Explosion Proof Timing Controls

AFFILIATE—LINE ELECTRIC COMPANY

Timers that Control the Pulse Beat of Industry

INDUSTRIAL TIMER CORPORATION

INDUSTRIAL TIMER CORPORATION
1419 McCARTER HIGHWAY, NEWARK 4, N. J.

 CIRCLE 58 ON READER-SERVICE CARD CIRCLE 59 ON READER-SERVICE CARD→

105 db gain in 60 mc I-F strip

Six-stage, 90 db gain, silicon i-f amplifier designed and built by TI's Apparatus division.

Write on your company letterhead for 105 db gain, eight stage, 60-mc i-f amplifier applications brochure.

...with TI 3N35 silicon transistors

105 db I-F STRIP CHARACTERISTICS

Bandwidth: 20 mc at 3-db down

Center Frequency: 60 mc

No neutralization required

The high gain of TI 3N35 transistors at high frequencies permits mismatch in the interstage coupling networks to eliminate complicated neutralizing circuitry. You save extra component costs, design with ease and gain added reliability ... because the mismatch in this application sacrifices only 2.55 db gain per stage!

Designed for your high frequency oscillators, i-f, r-f, and video amplifier circuits, the TI 3N35 features ... 20-db power gain at 70 mc ... typical 150-mc alpha cutoff ... operation to 150°C. These characteristics make transistorization feasible for radar, communications, missile, and other high reliability military applications.

In commercial production at TI for two years, the 3N35 has a product-proved record of high performance and high reliability. These units are *in stock now!* For *immediate delivery,* contact your nearby TI distributor for 1-249 quantities at factory prices ... or call on your nearest TI sales office for production quantities.

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SR-4® LOAD CELL

MEASURE WEIGHT, THRUST AND LOAD THIS MODERN WAY

B-L-H SR-4 Load Cells offer a dependable, accurate way to measure weight, thrust and load. Rugged and compact, they operate accurately under widely diverse conditions and are used to measure jet and rocket engine thrust, to determine center of gravity, to weigh loads at rest or in motion, and to control batch and continuous processes. Output permits local or remote instrumentation . . . indicators, recorders, printers, etc.

Available with capacities of from 50 to 200,000 lb. (compression) or 50 to 100,000 lb. (tension or compression), standard SR-4 Load Cells may be furnished with calibration accuracies of either ±0.25% or ±0.10% of rated capacity, depending on your requirements. Special capacities and/or characteristics can be furnished on order.

SR-4 Load Cells use accurately-matched SR-4 Bonded Strain Gages to detect the minute dimension changes of a central load column under tension or compression. They are hermetically sealed, are unaffected by dust, grease, moisture, corrosive atmospheres, etc.

For more data on B-L-H SR-4 cells, write Dept. **6-C** for a copy of Bulletin 4301. Or let us send a B-L-H man to see you at your convenience.

SR-4® LOAD CELL ADVANTAGES

- No moving parts
- High accuracy and repeatability
- Rugged, compact construction
- Long, economical service life

FIRST in forces measurement

BALDWIN · LIMA · HAMILTON

Electronics & Instrumentation Division

Waltham, Mass.

SR-4® Strain Gages • Transducers • Testing Machines

Announcing Epsco's **NEW**

DVOM

ADVANCE IN DIGITAL VOLT-OHM METERS

½ ACTUAL SIZE

FULLY TRANSISTORIZED

No Stepping Switches • No Relays

• **VERSATILE** accurately measures both resistances and AC-DC voltages and counts external events, too! Directly drives printers, punches and memory storage units and can be directly used as a bi-directional telemeter.

• **FAST** less than 2 millisecond reading time . . . up to 100 completely independent measurements per second for any system use.

• **EASY TO READ** in-line, in-plane visual display . . . lamp life up to 10,000 hours . . . numerals 1⅛ inch high . . . automatic indication of polarity, decimal point and mode of operation

True dependability and versatility have at long last come to digital volt-ohm meters in EPSCO'S new DVOM. Fully transistorized . . . adjustment-free . . . no stepping switches or relays. Provides precise numerical measurement of AC-DC voltages, resistances . . . fast, accurate visual or printed quality control data . . . high-speed data acquisition for direct print-out or storage . . . remote indication and data transmission over a single line. Compact, lightweight, portable — also for rack-mounting. Write for Bulletin 95801, Epsco, Inc., Equipment Division, 588 Commonwealth Ave., Boston 15, Mass.; in the West: Epsco-West, 125 E. Orangethorpe Ave., Anaheim, California

DVOM price.....$1,475

Ask for a demonstration.

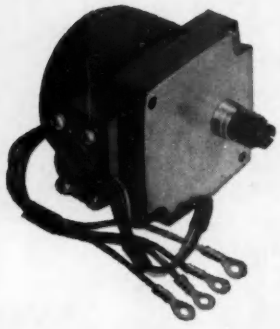
Epsco

First in data control

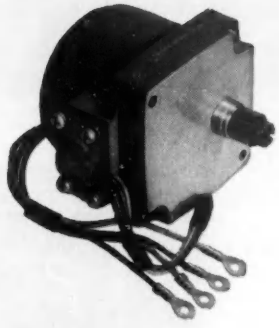
BROWN MOTORS

. . . for chart drives, servos, balancing circuits

STACK-TYPE MOTORS
These newly designed motors have such maintenance saving features as: sectional housing . . . wick-type lubrication . . . printed circuits . . . ball bearings . . . shock absorbers . . . alignment keying rings. Any major part replaceable in two minutes.



OIL-SEALED MOTORS
These field-proven motors feature self-lubrication, have shock absorbers, are totally enclosed and oil sealed.



MILITARY MOTORS
These are oil-sealed-type motors, modified to comply with MIL-M-17059. Housing is treated as specified in MIL-C-5541, and leads are fungus resistant as per MIL-V-173.

. . . All motors are available in two phase and synchronous models

SPECIFICATIONS (applicable to all motors described above)

Two Phase Induction Motor

Nominal No Load R.P.M.*	Gear Ratio	Intermittent Rated Load (oz.-in.)	Maximum Starting Torque (oz.-in.)	Power (Watts) Loaded	Current (amp.) †Loaded	Temp. Rise °F
330	44:1	4	10	11.5	0.11	70
144	10:1	5	20	11.5	0.11	70
48	30:1	15	60	11.5	0.11	70
23	60:1	30	110	11.5	0.11	70

Synchronous

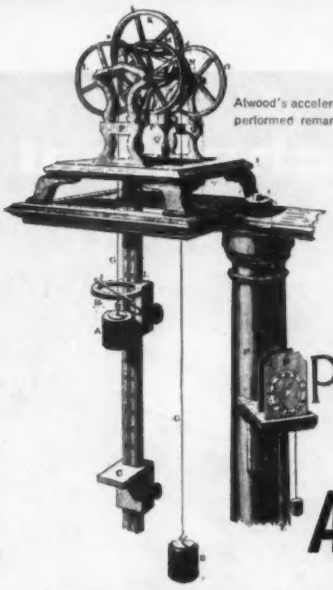
R.P.M.*	Gear Ratio	Pull-In Torque Minimum (oz.-in.)	Continuous Torque (oz.-in.)	Power (Watts) Loaded	Current (amps.) Loaded	Temp. Rise °F
180	10:1	12	12	24.0	0.21	100
180	10:1	2	2	11.5	0.11	65
90	20:1	14	12	11.5	0.11	65
60	30:1	21	18	11.5	0.11	65
30	60:1	42	36	11.5	0.11	65

*1/6 less at 50 cycles
†Field winding 11.0 watts, balance in amplifier winding
Note: Some speeds available at 25 cycles

MINNEAPOLIS-HONEYWELL, Wayne and Windrim Aves., Phila. 44, Pa.

Honeywell

First in Control



Atwood's accelerometer, in 1846, performed remarkably well for its day.

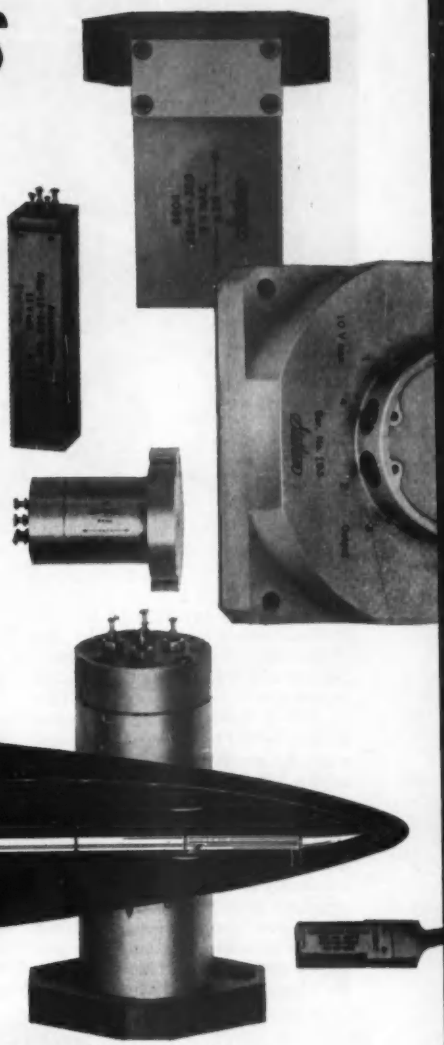
PROGRESS IN MEASUREMENT

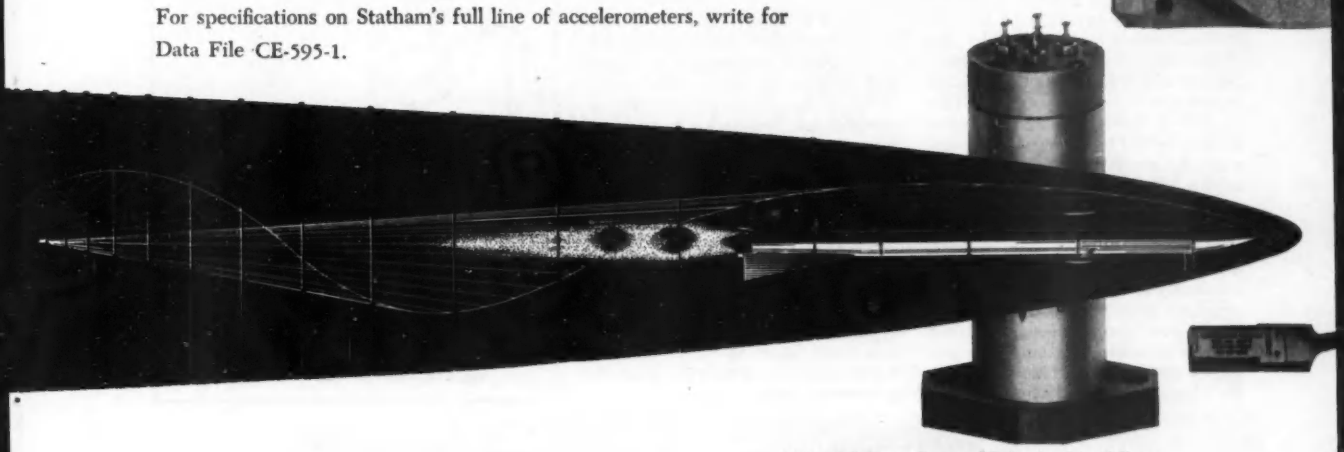
ACCELEROMETERS

Now, because of their outstanding accuracy, reliability, and service life, Statham accelerometers are specified in practically every major missile project in the free world. These versatile instruments are measuring with equal facility and utmost accuracy both the powerful linear accelerations associated with launchings, and the almost infinitesimal angular accelerations involved in spatial navigation.

The precision of Statham instruments is typical of the "progress in measurement" that has come about within a single lifetime; however, the need for progress has not ended. Using the same inventiveness that produced the unbonded strain gage and made possible the present "state of the art," Statham research and development continues to set the pace for advancement in accurate, dependable measurement for ground, airborne, and space environments.

For specifications on Statham's full line of accelerometers, write for Data File CE-595-1.





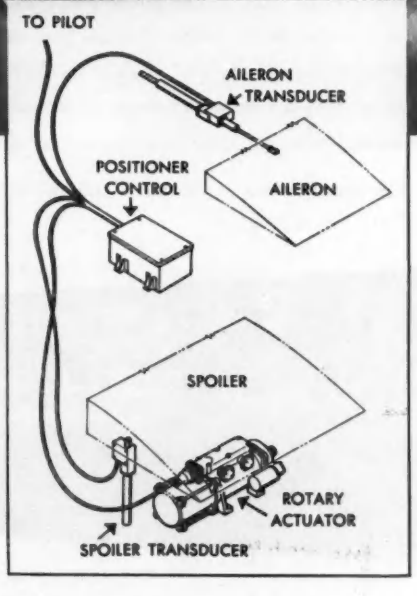
Unbonded Strain Gage and Inductive Liquid Rotor Angular Accelerometers
Unbonded Strain Gage and Inductive Liquid Rotor Linear Accelerometers
Temperature-Controlled Accelerometers

Statham INSTRUMENTS, INC. *12401 West Olympic Boulevard, Los Angeles 64, California*

CIRCLE 63 ON READER-SERVICE CARD

Advanced electro-mechanical systems

AiResearch Spoiler Servo Control System for Canadair's CL-28 and CL-44



A substantial increase in aileron effectiveness is achieved by the AiResearch Spoiler Servo Control System which augments the function of the aileron by increasing the rate of roll of the aircraft. Full spoiler surface travel is achieved in 0.5 seconds by electromagnetic clutching of the 4 H.P. power servo.

The added control surface of the Spoiler Control Servo System operates on the inboard side of each aileron. This AiResearch electro-mechanical system automatically synchronizes the spoiler control surface to move simultaneously with the aileron by utilizing a magnetic amplifier and position transducers in the closed loop servo system.

This new Spoiler Control System is but one of the many types of electro-mechanical systems developed and manufactured by AiResearch. Other recent examples include radar antenna positioning equipment, magnetron and Klystron tuning devices, and safe-arm mechanisms for missile igniting.

The company's more than 20 years of experience in the development and manufacture of electro-mechanical equipment extends into aircraft, ground handling, ordnance and missile systems of all types. AiResearch capability and system responsibility can meet your specific electro-mechanical requirements. Your inquiries are invited.

ENGINEERING REPRESENTATIVES: AIRSUPPLY AND AERO ENGINEERING, OFFICES IN MAJOR CITIES

THE GARRETT CORPORATION

AiResearch Manufacturing Divisions

Los Angeles 45, California • Phoenix, Arizona

Systems, Packages and Components for: AIRCRAFT, MISSILE, ELECTRONIC, NUCLEAR AND INDUSTRIAL APPLICATIONS

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SQUEEZING HIGH POWER INTO small packages

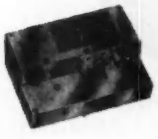
Unhampered by traditional thinking, TELECHROME engineers have developed an entirely new concept in telemetering equipment — unequalled in compactness, ruggedness and dependability.

TELEMETERING TRANSMITTERS

FM/FM or PDM/FM Crystal Controlled

215 to 260 Megacycles

Model 1472



4" x 1.5" x 2.7"
2 Watts

Model 1463

5 1/32" x 3 13/16" x 4"
15 to 30 Watts

Model 1462

6" x 4 1/4" x 3 1/4"
50 to 80 Watts

Model 1488A

6.5" x 4" x 3.25" RF Amplifier
2 watts in — 100 watts out

SUB-CARRIER OSCILLATOR.
Model 800C — 1.5" x 1.9" x 2.45"

Deviation stability ±1% of band width. Deviation linearity less than 1% of band width under all conditions measured from a straight line drawn between end points.

TELECHROME

synchros

in the popular Size 8 line

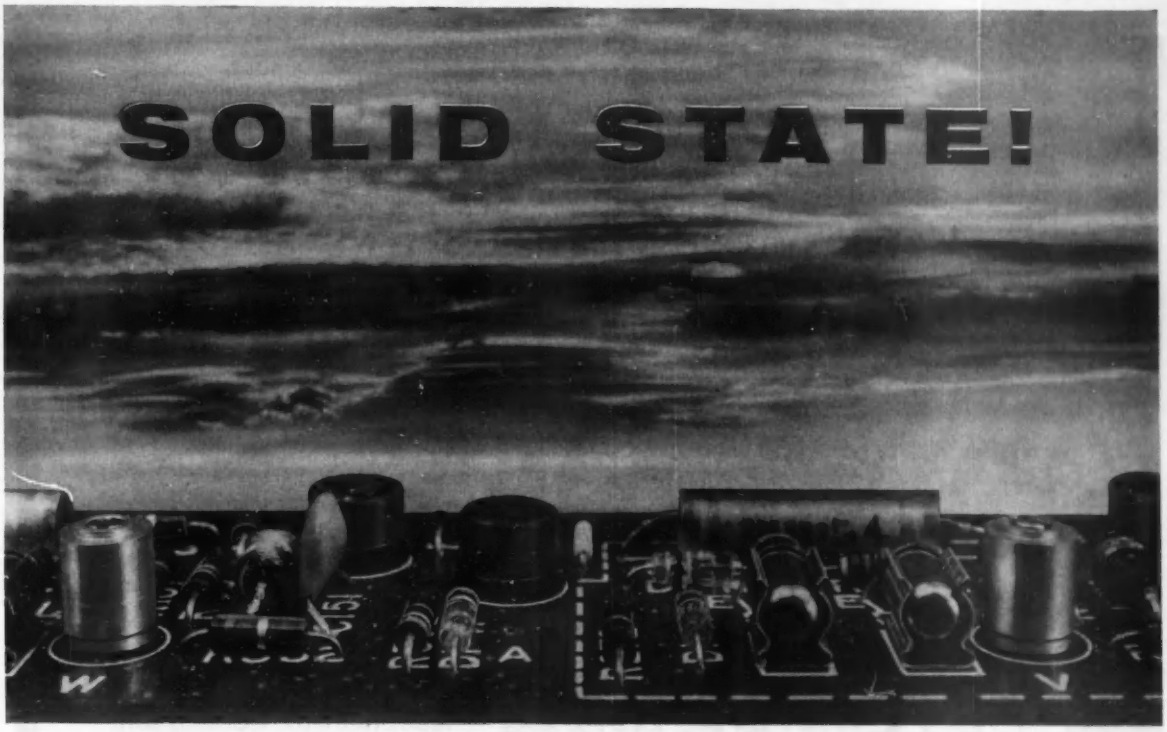
are now in production at Daystrom Transicoil. The new size 8 Synchro Line includes high quality, top performance transmitters, control transformers, differentials, and repeaters. Frame size equal to BuOrd Size 8. Operation: 115V 400 cycles or 26V 400 cycles. Accuracies to ±5′ are available. Corrosion resistant construction throughout. Conforms to MIL-E-5272-A.

Write for complete specifications. Be sure to ask about our 24 Hour Service for rotating components. Daystrom Transicoil, Division of Daystrom, Inc., Worcester, Montgomery County, Pa. Phone JUNO 4-2421. In Canada: Daystrom, Ltd., 840 Caledonia Rd., Toronto 19, Ont. Foreign: Daystrom International Div., 100 Empire St., Newark 12, N. J.

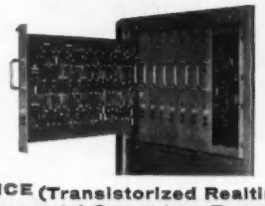
DAYSTROM TRANSICOIL DIVISION OF DAYSTROM, INC.

Representatives in Canada and Other Foreign Countries

"SEE US AT THE I.R.E. SHOW—BOOTH 1808"

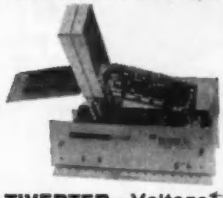


"New Look on the Horizon"—COMPLETELY TRANSISTORIZED DIGITAL COMPUTERS, CONVERTERS, SYSTEMS AND MODULES



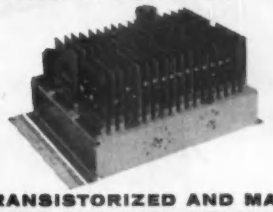
TRICE (Transistorized Realtime Incremental Computer, Expandable) — THE WORLD'S MOST ADVANCED COMPUTER

TRICE is a completely solid state high speed (100,000 iterations per second) incremental computer that operates at the speed of analog computers with the accuracy and flexibility of digital devices. Independent computing elements, operating in parallel, permit the computer's size to be adjusted to meet varying applications. Completely digital, TRICE can be used in simulating nonlinear and open loop systems without the limitations of analog methods. Because of its very high speed, it is particularly applicable to various operational systems including the computation of coordinate transformations, missile trajectories, Fourier spectra and satellite orbits.



MULTIVERTER—Voltage-Digital Converter and Related Products

The MULTIVERTER was developed by Packard Bell Computer to meet industry's need for fast, accurate and reliable conversion between voltage and digital information representation for use in data collection and transmission systems, in digital control systems and in interconnecting computers such as TRICE with analog devices. The MULTIVERTER is the first completely solid state high speed (4 microseconds per bit) conversion system accurate to .01%. Accessories include a compatible solid state multiplexer and the first high speed solid state Sample and Hold device.



TRANSISTORIZED AND MAGNETIC DIGITAL MODULES

A variety of solid state modules are available for the construction of special systems. The following transistorized types are available: medium speed (nominally 200KC) AC coupled modules, high speed (nominally 4 mc) AC coupled modules, medium speed DC coupled modules, special high temperature modules and magnetic modules at low (20KC) and medium (100KC) speed together with the *first* commercially available *transistor* driving circuits.

CUSTOM DIGITAL CONTROL AND COMPUTING SYSTEMS

Packard Bell Computer uses the components and techniques described to produce custom digital systems for Missile Impact Prediction, On Line Data Processing, Data Recording, Coordinate Conversion, Stable Platform Calculations, Orbit Predictions, Guidance and Control and Solid State Automatic Checkout.

PACKARD BELL COMPUTER CORP.

A subsidiary of Packard Bell Electronics

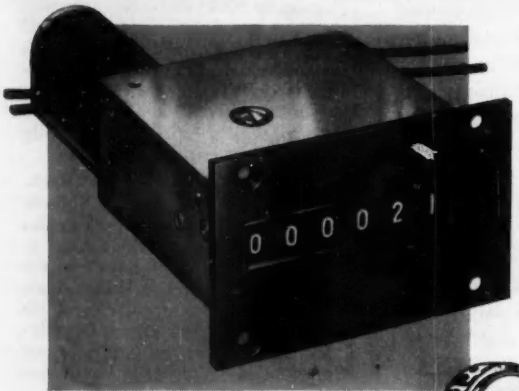
1905 S. Armacost Ave. • Los Angeles 25, California • GR 8-4247

CIRCLE 67 ON READER-SERVICE CARD

How can you prove your guarantee unless your product can COUNT?

When customers come after you with claims concerning your product's performance, can you prove your position? You can, to everyone's satisfaction, if Veeder-Root Counters are built into your product as standard, integral parts. For then your customers have Facts-in-Figures on actual performance on the job, figures that settle arguments fairly and squarely . . . in fact, often prevent misunderstandings in the first place. What's more, when you build-in V-R Counters, you build up your product's sales appeal . . . as many manufacturers have found to their profit. So can you. Write and find out how.

You always "Know the score" when you count on Veeder-Root!



NEW Panel-Mounted, High Speed Electro-Magnetic Counter

Series 1591 Counters are ideal for DC applications requiring accuracy and long life at very high speeds. 4 or 6 figures. Instant pushbutton reset or remote electrical reset.

Electrical Contactor

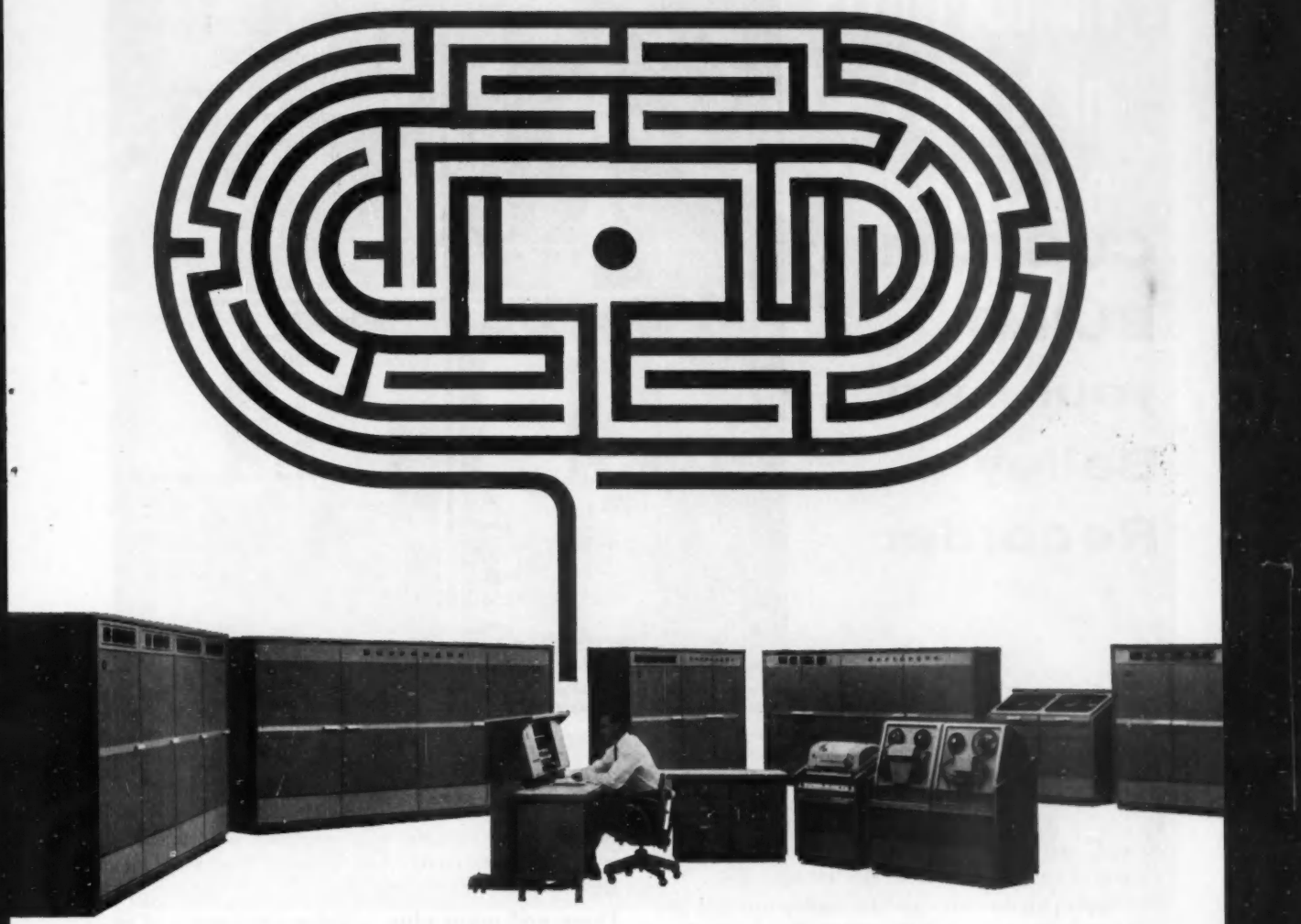
Assures positive actuation of 1591 Counters. Drive by lever or forked coupling.

Everyone can Count on

Veeder-Root Inc.

HARTFORD 2, CONNECTICUT

Hartford, Conn. • Greenville, S. C. • Altoona, Pa. • Chicago
New York • Los Angeles • San Francisco • Montreal
Offices and Agents in Principal Cities



solving today's problems today: Burroughs 220 Computer

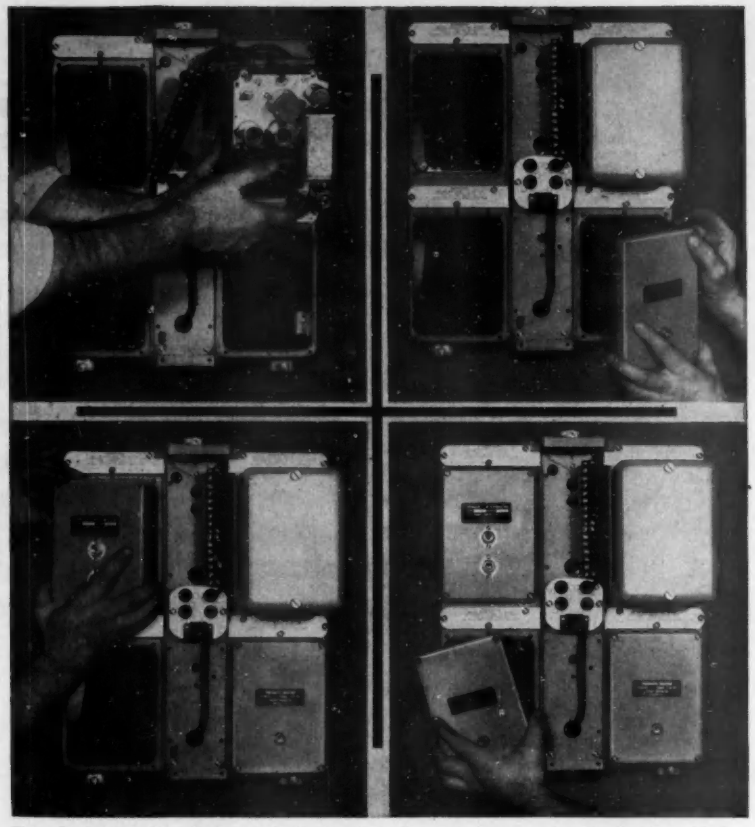
In scientific computation and business data processing, the new Burroughs 220 is delivering tangible results today. Linking a powerful digital computer to equally powerful input-output subsystems, the 220 offers balanced performance at the lowest application cost. Its expandable core memory, built-in floating decimal arithmetic, vast Datafile magnetic tape capacity and the multiple-card processing ability of Cardatron make this the most powerful system available in the medium price field. The 220 is just one part of a complete line of advanced Burroughs electronic data processing equipment...now in production...now at work in hundreds of installations...supported by an outstanding team of computer specialists. Write today for 220 brochure, ElectroData Division, Pasadena, California.

Burroughs Corporation

"NEW DIMENSIONS/in electronics and data processing systems"

CIRCLE 69 ON READER-SERVICE CARD

CUSTOM BUILD your own Bailey Recorder



These four views of the back of a Bailey Recorder show how four plug-in units may be added as needed to meet almost any recorder application.

The freedom and flexibility of "do-it-yourself" instrumentation is yours in the Bailey Recorder. A variety of plug-in units make it possible to record, control, and retransmit any variable that can be converted to a pneumatic or electric signal.

The basic plug-in units are the Bailey a-c and d-c Electronic Receivers and Pneumatic Receivers. Any four of these may be used in one recorder, intermixed in any way, to provide four continuous records on one chart.

For automatic control, other plug-in units are available.

For square root extraction or linear integration, there are two plug-in variations of the Bailey Integrator.

When you want a pneumatic signal that varies according to a pre-set pattern plug in a Bailey Program Controller.

Periodic running time of a condition or process is recorded on the chart when a Bailey Running Time Recorder is used.

These and other plug-in units are described in Product Specification E12-5. Some companies stock Bailey Recorder cases and assorted plug-in units. As instrumentation and control needs arise they build up the kind of recorder-controller required, using the proper plug-in units from stock. Unmatched versatility such as this means lower instrumentation costs.

For the complete story of how easily you can custom build this recorder to your needs, see your Bailey Engineer. G43-1

Instruments and controls for power and process

BAILEY METER COMPANY

1079 IVANHOE ROAD • CLEVELAND 10, OHIO

In Canada—Bailey Meter Company Limited, Montreal

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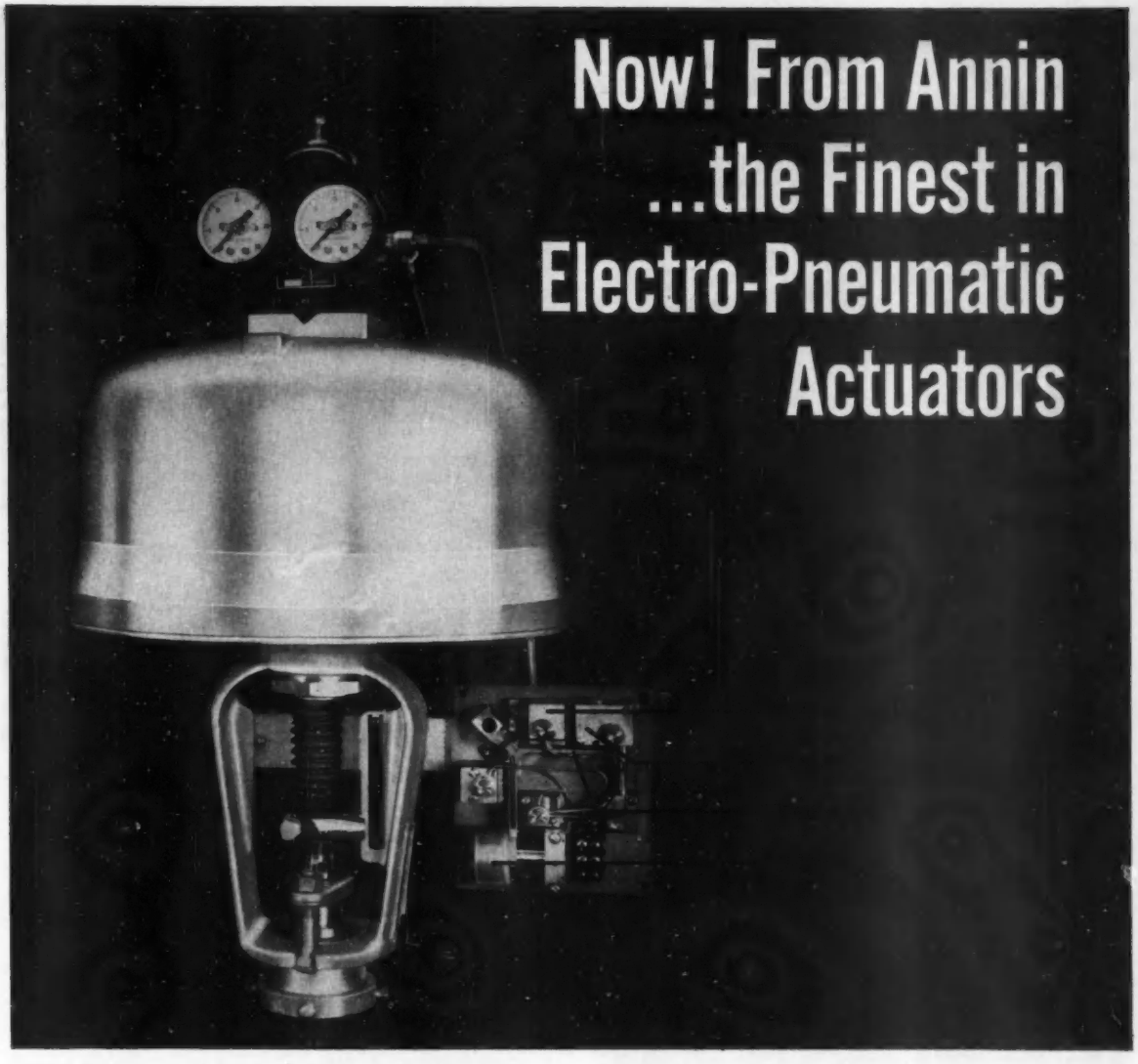


Now! From Annin ...the Finest in Electro-Pneumatic Actuators

Annin's Model 30,000 transducer, coupled with the Annin Domotor, gives you greater range of adjustment, unequalled stability, and exceptional dynamic characteristics

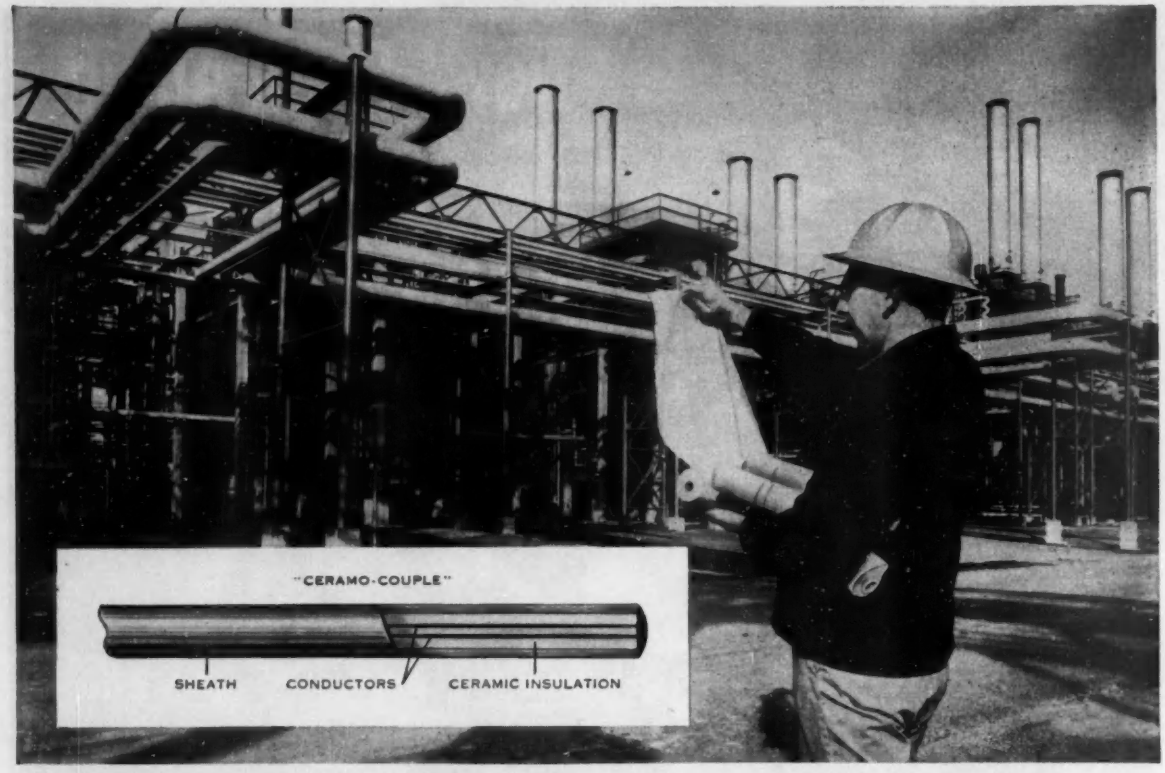
The Model 30,000 has been developed to provide process engineers with a practical transducing element for converting a small electrical signal to an accurate and stable pneumatic output pressure. It embodies only four basic sub-assemblies, which minimize motion and wear, simplify adjustment and installation. The Model 30,000 features full-scale zero adjustment and a wide range of span settings for split range and sequencing applications. Absence of complex components, together with minimum installation,contribute to low maintenance. Linearity and accuracy reach a new high in electro-pneumatic transducing with the Model 30,000. *Technical data on request*

Send for your copy
of Annin's new Catalog 1500-D

Annin VALVES

THE ANNIN COMPANY Division of The Annin Corporation
1040 S. Vail Ave., Montebello, California

CIRCLE 71 ON READER-SERVICE CARD



Process engineer at Sun Oil Refinery examining temperature measurements from "Ceramo" thermocouples.

Ceramo® Thermocouples Help Sun Oil Prevent Furnace Tube Failure

Thermo Electric's Versatile "Ceramo" Solves Another Problem

The Sun Oil Company refinery at Marcus Hook, Pa., found the answer to a difficult problem—preventing tube failure in their process heaters—with T-E's "Ceramo-Couples."

As coking and scaling build up within these tubes, heat transfer is reduced and tube temperatures rise. Unchecked, this condition can eventually result in costly, unscheduled shutdowns and potentially dangerous tube rupture.

Sun Oil also had another problem—rapid thermocouple failure. To measure tube skin temperatures from 500—1200° F. and withstand furnace temperatures to 1800° F., they were using 8-gage, insulated, pencil-type T/C's without protection tubes. Wires became brittle and soon broke. Hot junctions separated from the tube wall and read gas instead of tube temperatures. Process engineers had no confidence in readings. Costly, time-consuming installation of new T/C's was needed after every furnace shut-down.

Sun Oil went looking for a better thermocouple. They found it in T-E's "Ceramo"—ceramic insulated conductors encased in overall metal sheathing. Their 3/16" O. D. "Ceramo-Couples" have 20-gage Chromel-Alumel conductors and stainless steel sheathing. Thermocouple life was greatly increased, replacement was cut in half. Reliable readings from "Ceramo" permitted operation of process heaters at higher temperatures—thereby increasing production. "Ceramo's" ability to be bent on a small radius without shorting or grounding simplified installation. And "Ceramo" flexed with the differential motion between tubes and furnace walls.

Sun Oil now has about 300 "Ceramo-Couples" in use at Marcus Hook in 5 to 32 ft. lengths. During the 5 years "Ceramo" has been in use, Sun Oil has had no furnace tube failure or unscheduled shut-downs from faulty temperature measurement.

If you have problems of high temperature, moisture, abrasion, corrosion or difficult installation, investigate T-E's "Ceramo." Only "Ceramo" has the quality of materials and construction to meet all these needs.

Write For EDS-45—B.

Thermo Electric CO., INC.
SADDLE BROOK, NEW JERSEY
In Canada: THERMO ELECTRIC (Canada) LTD., Brampton, Ontario

WE POINT WITH PRIDE

We point with massive and pardonable pride to our latest achievement—the new, reliable Mincom Model C-100 Instrumentation Recorder/Reproducer. Six speeds record frequencies from 50 cps to 100 kc. Only 500 watts input for 14 track system (all-transistorized electronics). No cooling necessary. No mechanical brakes. Only 0.1% flutter and wow. Instant push-button speed control, no belt changes. Interested? Write for specifications.

MINCOM

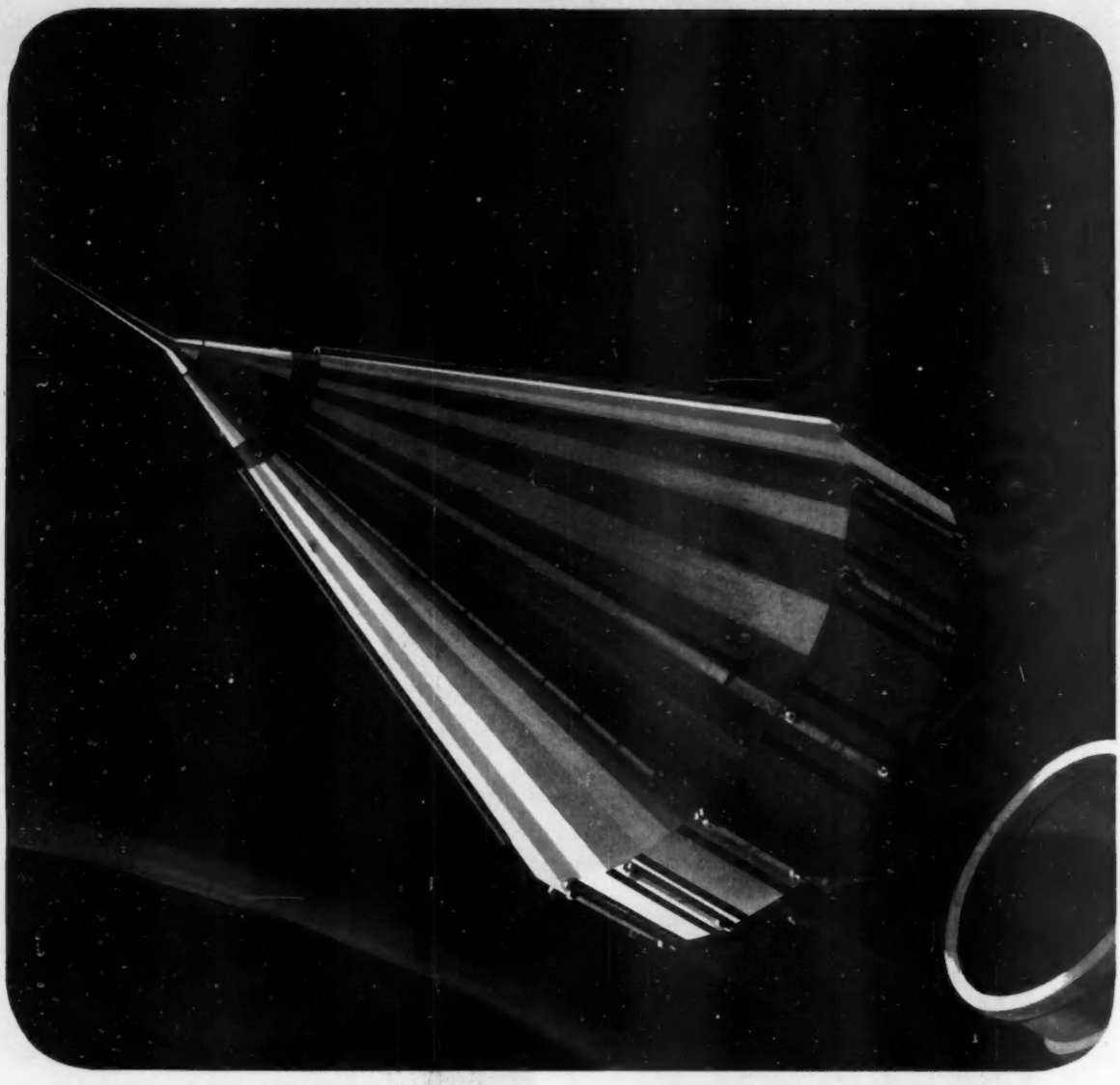
2049 SOUTH BARRINGTON AVENUE
LOS ANGELES 25, CALIFORNIA
TELETYPE: WEST LOS ANGELES 6742

3M

MINNESOTA MINING AND MANUFACTURING COMPANY ... WHERE RESEARCH IS THE KEY TO TOMORROW

CIRCLE 73 ON READER-SERVICE CARD

NOTABLE ACHIEVEMENTS AT JPL...



PIONEERING IN SPACE RESEARCH

Another important advance in man's knowledge of outer space was provided by Pioneer III. This, like many others of a continuing series of space probes, was designed and launched by Jet Propulsion Laboratory for the National Aeronautics and Space Administration. JPL is administered by the California Institute of Technology for NASA.

During its flight of 38 hours, Pioneer III was tracked by JPL tracking stations for 25 hours, the maximum time it was above the horizon for these stations.

The primary scientific experiment was the measurement of the radiation environment at distances far from the Earth and telemetering data of fundamental scientific value was recorded for 22 hours. Analysis of this data revealed, at 10,000 miles from the Earth, the existence of a belt of high radiation intensity greater than that observed by the Explorer satellites.

This discovery is of vital importance as it poses new problems affecting the dispatch of future vehicles into space. The study and solution of such problems compose a large part of the research and development programs now in extensive operation at the Laboratory.

jpl

CALIFORNIA INSTITUTE OF TECHNOLOGY
JET PROPULSION LABORATORY
A Research Facility operated for the National Aeronautics and Space Administration
PASADENA, CALIFORNIA

OPPORTUNITIES NOW OPEN IN THESE CLASSIFICATIONS ▶ APPLIED MATHEMATICIANS . ENGINEERING PHYSICISTS . COMPUTER ANALYSTS . IBM-704 PROGRAMMERS AERONAUTICAL ENGINEERS . RESEARCH ANALYSTS . DESIGN ENGINEERS . STRUCTURES AND DEVELOPMENT ENGINEERS

 CIRCLE 74 ON READER-SERVICE CARD

CIRCLE 75 ON READER-SERVICE CARD

It takes a TEAM
to solve timing problems

The control of time is an extremely complex science that demands a thorough knowledge of many individual technologies. For this reason, Haydon maintains a team of engineering specialists to provide the reservoir of skill, knowledge, experience, and creative ability necessary to solve industry's timing problems.

When you submit a timing problem to Haydon, it's handled by a team of specialists – *not* an individual engineer. And you can be sure the Haydon Timing Team is equipped with all the electric, electronic, mechanical and manufacturing know-how needed to analyze your requirements and develop the best possible new or modified timing unit for your specific application.

Correctly designed and efficiently manufactured, Haydon timing devices are exhaustively tested before release to a customer. The results are uniformly high quality devices that are known for fine performance, and long life. May we put our Timing Team to work for you?

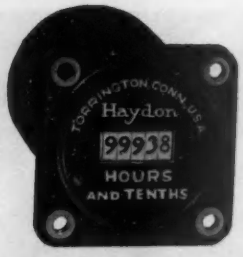
A few units from the complete Haydon line are shown at the right. Send now for further information, outlining your requirements.

Haydon
AT TORRINGTON

DIVISION OF
GENERAL TIME CORPORATION

2327 EAST ELM STREET
TORRINGTON, CONNECTICUT

Headquarters for Timing

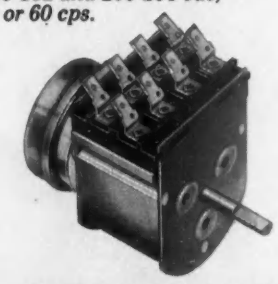


ELAPSED TIME INDICATOR ED-71

Compact, low-cost instrument for machine tools, communications equipment and other commercial applications where an accurate record of operating time is desired. Time Registered: 9,999.9 hours. Weight: 5 oz. Voltages: 120 or 240 v, 60 cps. Power Required: 2.5 watts at 120 v, 60 cps.

A-C TIMING MOTORS

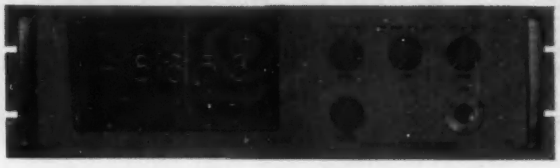
A complete line of synchronous, compact timing motors, speeds from 1/60 to 60 rpm. Guaranteed torques from 6 ounce-inches to 30 ounce-inches at 1 rpm. Voltage ranges 103-132 and 206-264 vac, 50 or 60 cps.



INTERVAL TIMER

Directly controls heavy duty electrical loads. Type AD can be supplied with up to 3 SPST switches. Type AT has 1 SPST switch only. Intervals available with dial and knob: 15, 60 and 180 minutes. Intervals to meet your specific requirements can be supplied. Voltages: 120 or 240 v, 50 and 60 cps. Switch Rating: 28 amps, 250 vac non-inductive; 1 hp, 240 vac.

First Digital Voltmeter With Mathematically Perfect Logic . . .



The first stepping switch voltmeter with mathematically perfect logic . . . and the first to be completely transistorized! It's the NLS V-34, the latest instrument to be developed by the originators of the digital voltmeter. The exclusive new digital logic of the NLS V-34 allows readings to be made without cycling stepping switches through all nine positions in each decade. For the first time, "needless nines" are eliminated . . . the result: longer switch life and shorter measuring time. Check the exclusive features listed below.

"NO NEEDLESS NINES"

FOR FASTER MEASUREMENTS AND GREATEST RELIABILITY

MATHEMATICALLY PERFECT LOGIC — No numbers change that absolutely do not have to change. Stable measurements can be made of varying voltages.

STEPPING SWITCHES SEALED IN OIL — Each stepping switch is mounted in an individual oil-filled container. No manual lubrication needed. Oil bath extends life by factor of ten.

PLUG-IN STEPPING SWITCH MODULES — Stepping switches can be replaced as quickly as plugging in the meter.

FIRST COMPLETELY TRANSISTORIZED DIGITAL VOLTMETER — Even logic functions are performed by semi-conductors. Switch points reduced to one-half those required by "completely transistorized" competitive meters. Only the NLS V-34 is transistorized to the fullest possible extent.

SPECIFICATIONS

Range to ±1000 volts . . . Ratio to ±.9999 . . . 10 Megohm input impedance . . . 0.01% accuracy . . . Automatic range and polarity changing . . . five-digit model also available.

See the NLS V-34 at the 1959 I.R.E. Show . . . and write today for complete information.

Originators of the Digital Voltmeter

non-linear systems, inc. DEL MAR (San Diego), CALIFORNIA

1959 IRE SHOW — Booths 3041-2

COMPARISON CHART

The few steps required by the NLS V-34 to make a typical measurement (3rd column) are compared with the many required by competitive meters. Note the blue "needless nines" in the middle column.

NO. OF STEPS	COMPETITIVE METERS	NLS V-34
0	+.8888	+.8888
1	+.8889	−.8888
2	+.8880	−.9888
3	+.8890	−.0888
4	+.8800	−.1888
5	+.8900	−.1988
6	+.8000	−.1088
7	+.9000	−.1188
8	+.0000	−.1198
9	−.0000	−.1108
10	−.0001	−.1118
11	−.0002	−.1119
12	−.0003	−.1110
13	−.0004	−.1111
14	−.0005	
15	−.0006	
16	−.0007	
17	−.0008	
18	−.0009	
19	−.0019	
20	−.0029	
21	−.0039	
22	−.0049	
23	−.0059	
24	−.0069	
25	−.0079	
26	−.0089	
27	−.0099	
28	−.0199	
29	−.0299	
30	−.0399	
31	−.0499	
32	−.0599	
33	−.0699	
34	−.0799	
35	−.0899	
36	−.0999	
37	−.1999	
38	−.1099	
39	−.1199	
40	−.1109	
41	−.1119	
42	−.1110	
43	−.1111	

THE MEASUREMENT IS COMPLETED IN JUST 13 STEPS BY THE NLS V-34

NLS — The Digital Voltmeter That Works . . . And Works . . . And Works!

KEARFOTT TACHOMETERS

...compact, light-weight, high-performance

Kearfott offers one of the broadest lines of precision tachometers in the industry. Light, compact and resistant to temperature, vibration and shock, they are available for a wide variety of applications.

Size 11 (R860)

Integrating Tachometers, special types of rate generators, are almost invariably provided integrally coupled to a motor. They feature tachometer generators of high output-to-null ratio and are temperature stabilized or compensated for highest accuracy integration, rate computation, etc. In addition to reducing the in-phase null level toward zero, errors due to temperature effects are minimized over a wide ambient range. Linearity, in some cases as low as .01%, is usually better than ±.1%, while phase shift is 0±1°. For extreme accuracy, models with low temperature coefficient drag cups are also available.

Rate Generators feature high output-to-null ratios and are designed for application as rate servos and to provide damping in very high gain systems. These Kearfott units offer high linearity, high output and low inertia and are often integrally coupled to a low inertia motor; in this design the in-phase null is virtually reduced to zero. Quadrature null is as low as .25% of the 1000 rpm outputs while harmonics seldom exceed .1% of the output at 1000 rpm.

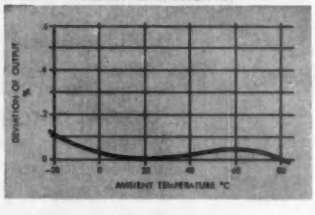
Damping Tachometers have relatively low output-to-null ratios and are designed primarily for damping purposes. They feature extremely low inertia and power consumption, linearity which is normally within ±.5%, and phase shift within 10° of reference. Kearfott damping tachometers are usually integrally coupled to a low inertia motor.

INTEGRATOR TACHOMETERS

(Typical Characteristics)

	Size 11 (R860)	Size 15 (T816)	Size 18 (V892)
Excitation Voltage (400 cps)	115	115	115
Volts at 0 rpm (RMS)	.020	.020	.010
Volts at 1000 rpm (RMS)	2.75	2.7	2.00
Phase shift at 3600 rpm	0°	0°	0°
Linearity at 0-3600 rpm	.07	.05	.07
Operating Temperature Range	−54° + 125°	−54° + 125°	−54° + 125°

TEMPERATURE

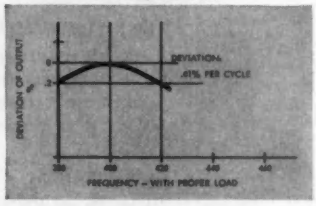


RATE TACHOMETERS | DAMPING TACHOMETERS

(Typical Characteristics)

	Size 15 (R800)	Size 18 (V806)	Size 8 (M824)	Size 10 (P822)	Size 11 (R809)
Excitation Voltage (400 cps)	115	115	26	115	115
Volts at 0 rpm (RMS)	.013	.026	.015	.019	.019
Volts at 1000 rpm (RMS)	3.1	3.0	.234	.450	.5
Phase shift at 3600 rpm	5°	4.5°	10°	5°	5°
Linearity at 0-3600 rpm	.25	.25	.3	.3	.3
Operating Temperature Range	−54° + 100°	−54° + 125°	−54° + 125°	−54° + 125°	−54° + 125°

FREQUENCY

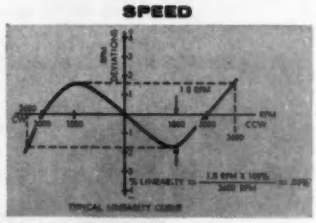


INTEGRAL SERVO MOTOR DATA

(Typical Characteristics)

	Size 8	Size 10	Size 11	Size 15	Size 18
No Load Speed (RPM)	5400	6600	5500	8000	8000
Stall Torque (oz. in.)	.3	.35	.55	.45	1.30
Excitation Voltage (400 cps)	18-40	26-40/20	115-40/20	115-40/20	115-115/57.5
Rotor Moment of Inertia (Gm.CM²)	1.3	.76	7.7	7.0	35
Operating Temperature Range	−54° + 100°	−54° + 125°	−54° + 125°	−54° + 125°	−54° + 125°
Unit Weight (incl. tachometer)—oz.	3.1	4.6	9.0	14.0	30

SPEED



Write for technical data

KEARFOTT COMPANY, INC., LITTLE FALLS, N. J.
A subsidiary of General Precision Equipment Corporation
Sales and Engineering Offices: 1378 Main Ave., Clifton, N. J.
Midwest Office: 23 W. Calendar Ave., La Grange, Ill.
South Central Office: 6211 Denton Drive, Dallas, Texas
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The many advance design features of the Trimpot have proved themselves repeatedly in major aircraft/missile systems and in commercial electronic equipment where reliability, accuracy plus miniature size are of prime importance. Pinpoint settings made on the Trimpot remain stable under the most severe environmental conditions. And—these units save important space—typical size is 1¼"x 5/16"x 3/16". Bourns offers the world's largest selection of leadscrew actuated potentiometers...over 500,000 units in distributors' warehouses across the nation to fill your orders. Before specifying, investigate Bourns Trimpot, the original leadscrew actuated potentiometer. Write for our new Model Summary Brochure #4 and list of stocking distributors.

ONLY BOURNS TRIMPOT® GIVES YOU ALL THESE OUTSTANDING FEATURES

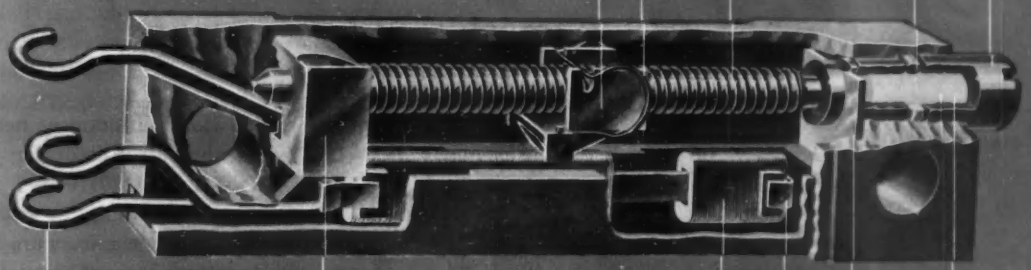
SPRING — Carriage spring provides positive no-slip performance during rotation plus a reliable idling feature at mechanical limits of travel.

LEAD SCREW — Stainless steel lead screw for low noise, high performance during rotation.

O-RING — Silicon rubber O-Ring seals potentiometer against humidity. Prevents flash-over to shaft head for high voltage operation.

SHAFT HEAD — Stainless steel with machined slot for screwdriver adjustment. Meets military salt spray requirements.

WIPER CARRIAGE — Gold-plated carriage is welded to precious metal wiper for low noise.



SOLDER TERMINALS — Tinned terminals are compact, yet large enough for easy soldering. Teflon-insulated leads and printed circuit pins are also available.

SILVERWELD® TERMINATION — Exclusive with Bourns potentiometers. Unequalled in ruggedness. A metal-to-metal bond from the terminal to the resistance wire.

PICK-OFF — Gold-plated beryllium copper pick-off maintains constant pressure on lead screw.

ELEMENT — Special ceramic element card for maximum reliability in precision wound with low-temperature-coefficient resistance wire.

SHAFT RETAINER — Shaft is locked in place for top performance under extreme shock, vibration and acceleration.

SHAFT INSULATOR — High-dielectric-strength, ceramic insulator isolates shaft head from internal circuits.

This cutaway of Model 224 is typical of the design of all Bourns potentiometers though some features vary from model to model.

ACTUAL SIZE

Most models available with insulated stranded leads, solder lugs or printed circuit pins in resistances from 10Ω to 1 Meg.

BOURNS
Laboratories, Inc.
P.O. Box 2112A, Riverside, California
Plants: Riverside, Calif. and Ames, Iowa

*TRADEMARK

Exclusive manufacturers of TRIMPOT®, TRIMIT®. Pioneers in potentiometer transducers for position, pressure and acceleration

DELCO POWER TRANSISTORS

NEW TYPES

MILITARY
COMMERCIAL

TYPICAL CHARACTERISTICS AT 25°C

EIA	2N297A*	2N297A	2N665**	2N553
Collector Diode Voltage (Max.)	60	60	80	80 volts
HFE (I_c=0.5A) (Range)	40-100	40-100	40-80	40-80
HFE (I_c=2A) (Min.)	20	20	20	20
I_{co} (2 volts, 25°C) (Max.)	200	200	50	50 μa
I_{co} (30 volts, 71°C) (Max.)	6	6	2	2 ma
F_{ae} (Min.)	5	5	20	20 kc
T (Max.)	95	95	95	95°C
Therm Res. (Max.)	2	2	2	2° C/W

*Mil. T 19500/36 (Sig. C.)
**Mil. T 19500/58 (Sig. C.)

NOTE: Military Types pass comprehensive electrical tests with a combined acceptance level of 1%.

Delco Radio announces new PNP germanium transistors in 2N553 series — the 2N297A and 2N665, designed to meet military specifications. These transistors are ideal as voltage and current regulators because of their extremely low leakage current characteristics. All are highly efficient in switching circuits and in servo amplifier applications, and all are in *volume* production! Write today for complete engineering data.

See you at IRE Show, Booth 1512.

DELCO RADIO
Division of General Motors • Kokomo, Indiana

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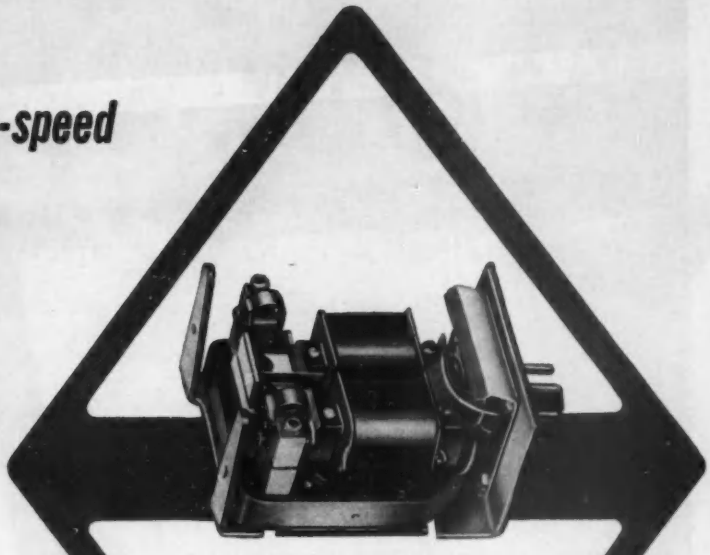
Small...sensitive...high-speed

POLAR RELAY

for billions of maintenance-free operations



New Type 204 Series PTW Polar Relay has octal plug mounting for universal use. Height, 2 13/16" plus 4 1/64" projection of mounting plug; width, 2 9/32" x 1 11/16". Type 202 has standard banana-type terminals; Type 203 has pin-type terminals.

HERE'S A 2-position Polar Relay that can be depended upon for switching a single circuit at high speeds through billions of operations—*without readjustment.*

Substantially smaller than other polar relays, the Automatic Electric Series PTW is designed for telegraph and teleprinter circuits—teletypewriter switching—teletypewriter repeater circuits—plus other industrial and military applications. Type 203 is completely interchangeable with Western Electric 255A relays.

Check these unique advantages

Because of its simple design and compact construction, the PTW costs substantially less than other relays you may have been using. It delivers lightning response (travel time as little as 0.7 of a millisecond!). And its design assures adjustments that stay put practically forever.

Series PTW Polar Relays are available with various type terminals to fit both new and existing applications—including surface mounting of Type 202 in replacement of Western Union Type 17 relay.

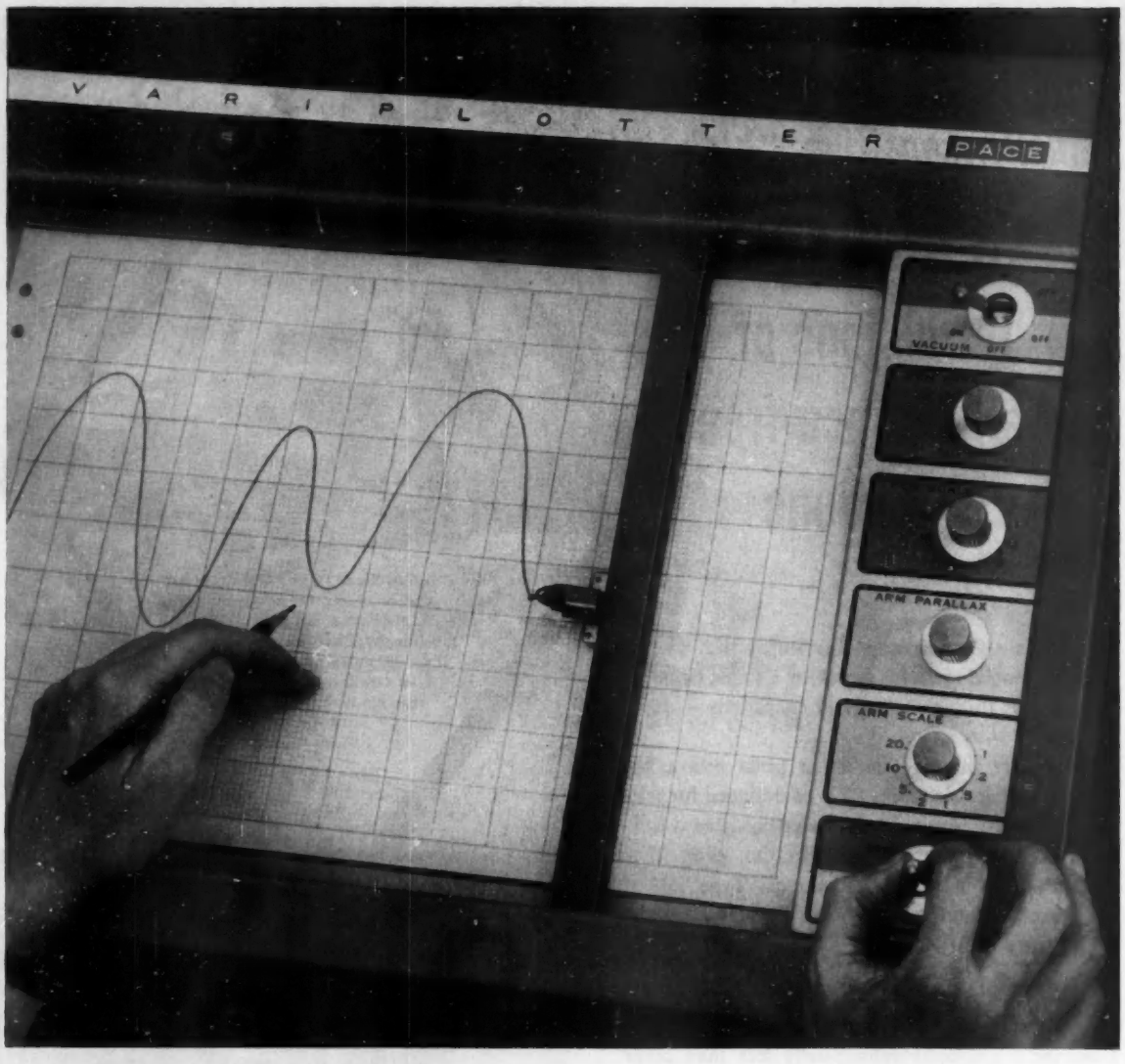
For full information, call or write Automatic Electric Sales Corporation, Northlake, Illinois. *In Canada:* Automatic Electric Sales (Canada) Ltd., Toronto. Offices in principal cities.

Automatic Electric Polar Relay is used in selector cabinet of Teleregister Corp. stock-quotation system. Teleregister design engineer, Jim Hartelius, shows how snap-on cover can be removed for visual inspection. He reports " . . . complete reliability . . . almost infinite life . . . virtually never gets out of adjustment."

AUTOMATIC ELECTRIC

Northlake, Illinois • Subsidiary of GENERAL TELEPHONE

CIRCLE 81 ON READER-SERVICE CARD



with **EAI** *portable X-Y plotter—*

you can convert data to graphic form quickly...accurately...reliably

With Electronic Associates' new Variplotter Model 1100E, data can be converted immediately to graphic form for quick, easy interpretation and understanding. Graphic display adds life to performance data—makes X and Y relationships instantly, unmistakably clear . . . provides permanent picture-like records of performance.

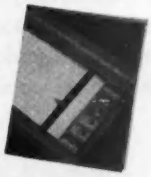
With the addition of accessories, versatile Variplotter will operate as a function generator, or will plot digital information from a keyboard. Its small size (23" L by 17½" W by 9½" H) and light weight (43 lbs.) make it a convenient laboratory tool.

The Variplotter combines high dynamic and static accuracy with a wide range of input sensitivities. Its rugged construction assures dependable, low-maintenance performance.

For name of our nearest representative write Dept. C.

VARIPLOTTER MODEL 1100E FEATURES:

- Portable table top size
- Vacuum hold down
- Wide range of input sensitivities
- High dynamic and static accuracy
- Rugged construction
- Ease of maintenance
- Differential inputs



For complete specifications write for Booklet AP-810C

ELECTRONIC ASSOCIATES Incorporated

ELECTRONIC ASSOCIATES INC.

LONG BRANCH, NEW JERSEY

 CIRCLE 82 ON READER-SERVICE CARD

The Southwest:
Three Superlatives in Control

Associate Editor Harry Karp, on a two-week tour of petroleum and chemical plants in the Gulf States, saw and heard some ambitious plans for process control.

In the Gulf Coast states, control engineers are talking most about three superlatives: 1) the most successful hardware—**the vapor chromatograph;** 2) the most promising new concept—**computing-control;** and 3) the most needed development—**closer user-maker cooperation.**

Chromatographs pay off

Look what has happened to vapor chromatography. It is now the workhorse instrument for process control. As a measuring instrument yielding composition information, the chromatograph has proved its ability to upgrade process throughput and quality. Its investment—about $15,000 for analyzer, sampling system, and installation—has been returned in startlingly short times. For example, Humble Oil's Dick Halter told the Texas A&M instrumentation symposium that 90 days of improved production paid for a chromatograph installation. At a chemical plant, CtE learned, a **chromatograph installation paid for itself in just three weeks!**

With operators placing full confidence on this instrument, the door has been opened to a fuller investigation of automatic control. At one oil company, a control engineer said the chromatograph makes feasible the full automatic control of a gasoline plant. Another petroleum refiner is directing its development efforts toward predicting the best controller settings for those applications in which the chromatograph output acts as the setpoint for conventional controllers correcting flow, pressure, or temperature. Such progress makes the economic justification of computing-control less difficult, because the chromatograph can deliver—direct to the computer—reliable data of significance to successful plant operation.

New hardware

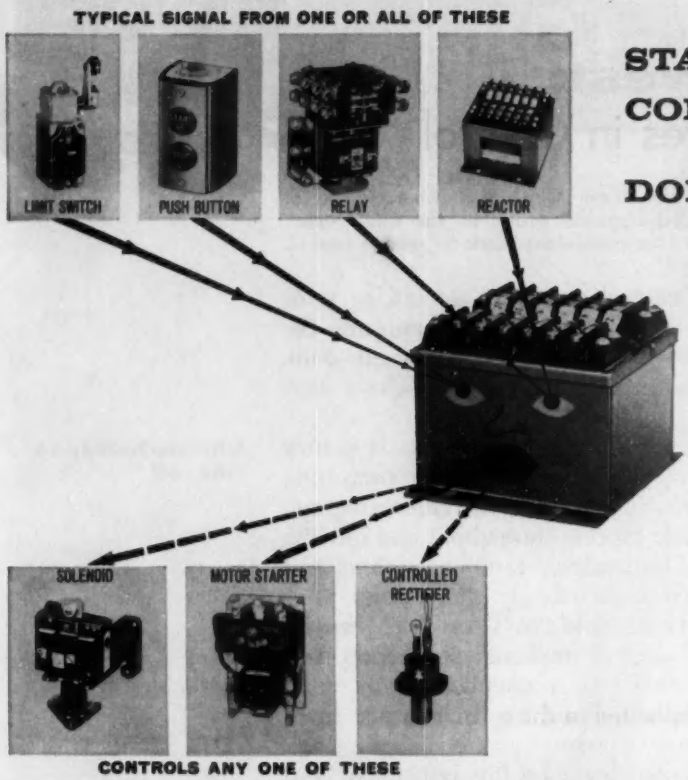
Hardware is already developing along these lines. Beckman Instruments, for example, is now showing its new chromatograph and control equipment. It measures the peak values of components' composition, stores these values as a pneumatic signal between 3 and 15 psi, takes peak-value ratio, and then uses the ratio to drive a control valve. Other manufacturers are building similar equipment. Some user companies have put together "jury-built" rigs to do the same thing.

Computing-Control coming fast

Just how fast computing-control is coming can be seen by the reports of a number of bids to meet formalized specifications for installations at petroleum and chemical plants in the Gulf Coast area. Texaco, Monsanto, and Goodrich (a system for a Kentucky

JOURNAL OF APPLIED CONTROL DEVICES THAT NEVER WEAR OUT

For Control Engineers Who Are Wearing Out Before Their Time



STATIC CONTROL COMPLICATED?

DON'T YOU BELIEVE IT!

An engineering friend of ours working on blast furnace controls uses a CONTROL switching reactor to take signals from a series of limit switches, temperature controllers, and relays to operate the solenoid which triggers the air blast motor. Dollars ahead he was when he saw this *selective* device would take signals from many sources, compile them, remember them, and when told to act (by the same standard input signals), leap into action. "So simple," he said—"nothing but the standard inputs we always use, switching reactor and outputs. If that's static control, I'm the new president of the C.S.R* Booster Club." *You, too, can beat the drum. Write for our catalog about Simple Static Control.*

**CONTROL Switching Reactor*

PUSH, PULL, CLICK, CLICK *(or how to feed a switching reactor)*

Persons who hear push-pull-click-click sounds in industrial plants are not to be suspected of an affinity for the razor business. They are listening to the music of push buttons, limit switches and relays, all feeding signals into CONTROL'S switching reactors (which are engaged in static control). Our reactor is *selective*. As you dictate, it responds to control voltages which add, which oppose, or which work in combination, regardless of source. What's more, our reactor can be fed by a transducer whose output is electrical—even if it doesn't say "push, pull" or "click, click."

If you have an affinity for money-making musical sounds, perhaps you'd like to know more about these CONTROL switching reactors. Write us.

CLICK, CLICK, PULL, PUSH *(or how a switching reactor feeds you)*

Here is the click-click-pull-push (output) side of the CONTROL switching reactor. Not only is it *selective* as to source and combinations of inputs, but it is a real bear for working such loads as solenoids, motor contactors and magnetic clutches. It shines, too, as a practical way of operating the new solid state thyratron from a variety of input sources. A reactor can control a single load up to 300-VA to a fare-thee-well. Loads are statically switched with nary a moving part. What's more, there is no auxiliary hardware (transformers, relays or single purpose logic units) to clutter the minds and hearts of your control engineers and purchasing agents.

Sizes? A complete range, including 15, 75, 150, and 300 VA. There's also one especially for the solid state thyratron. Why not write for more details about our CONTROL switching reactors.

Reliability begins with CONTROL

A DIVISION OF MAGNETICS, INC.

DEPT. CE-62, BUTLER, PENNSYLVANIA

VISIT OUR BOOTH 2339 AT THE IRE SHOW

 CIRCLE 83 ON READER-SERVICE CARD

plant) are still the only companies to officially announce plans. Others have been reluctant to go on record about their programs. But the probing questions asked by their engineers—about process dynamics, economic justification, and availability and reliability of equipment, what other companies are doing, tie-in with loggers and conventional controllers—indicates that computing-control is more than an academic subject. **Several announcements of plans for new on-line computing-control in Gulf Coast plants are coming before 1959 is over.**

Another area that has interest at a white heat is the role of **logger computers—and the success they have yet to show.** The ideas, techniques, and problems related to logging-computing will have their impact on computing-control, the next level of advanced operation.

User-maker help

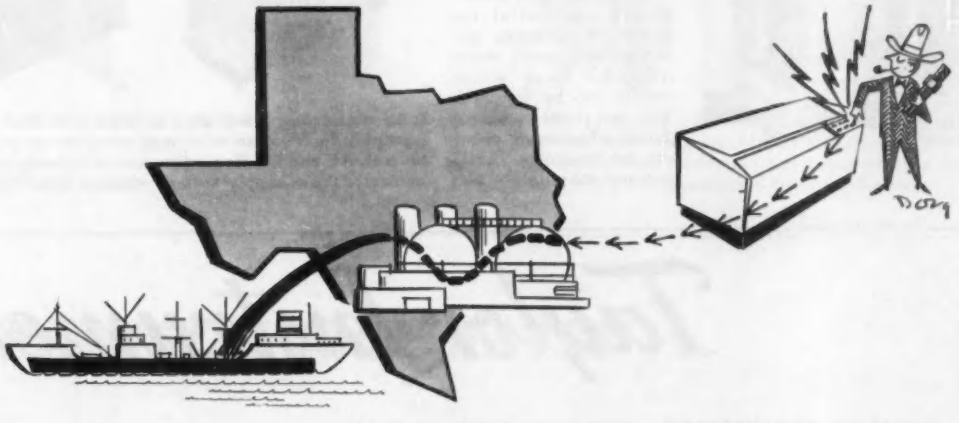
One problem that has developed is how to establish a reasonable relationship between system user and system maker. There is a growing realization of the dangers of one party pursuing individual gains without considering what's happening to the other. The lack of operating experience on such complex and costly systems—often involving previously untried techniques and hardware—keeps anybody from anticipating all the problems that can arise. The same deficiency keeps the user from writing tight and all-inclusive specifications, too.

One answer: both user and maker must be prepared for these unforeseen problems, and both must be prepared to spend time and money over what was incorporated in the contract.

Pays off for both

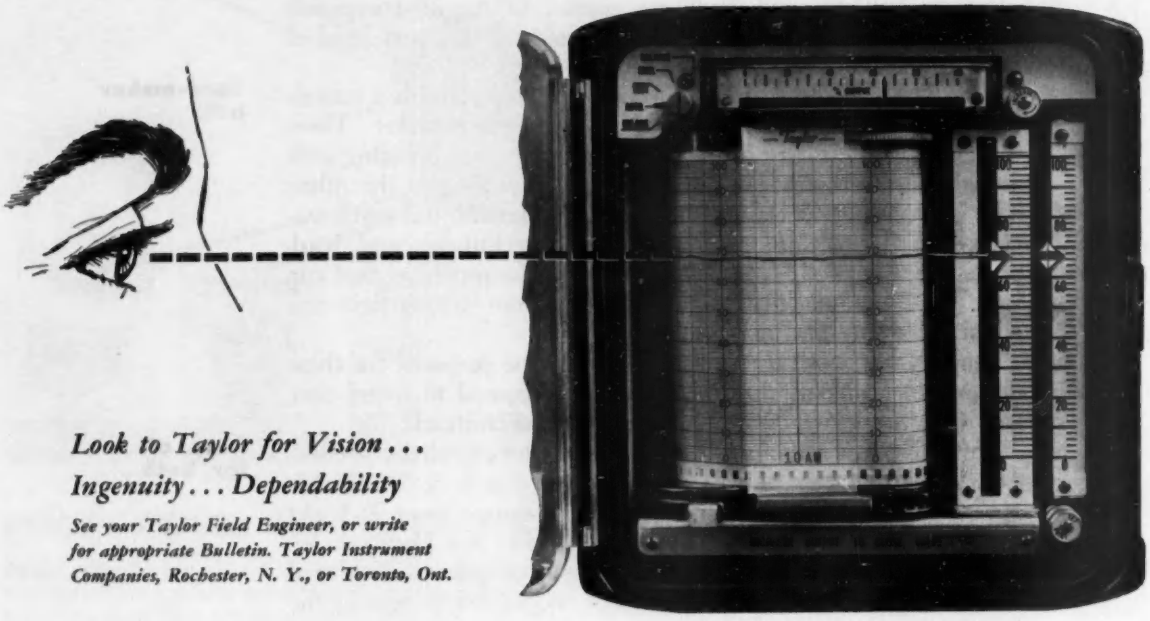
Two new installations offer good examples of what's needed. At the Esso (Baton Rouge) installation of Leeds & Northrup's operating guide computer and at the Louisiana Power & Light Co's Sterlington generating station installation of a Daystrom information system, unexpected snags appeared prior to field-trial acceptance tests. Both user and maker cooperated to correct the deficiencies.

The results are paying off for both. A prolonged successful run will prove the worth of the maker's equipment. Then evaluation of process data, gathered on the logger-computer, is likely to permit the user to upgrade the process operation, and perhaps eventually to close the loop with computing-control.



UNCONFUSED

in both Electronic and Pneumatic

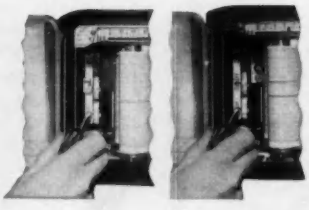


Look to Taylor for Vision . . .
Ingenuity . . . Dependability

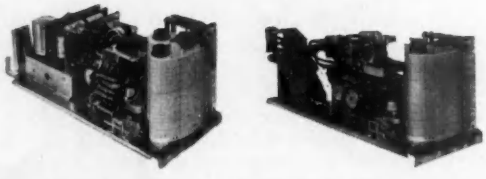
See your Taylor Field Engineer, or write for appropriate Bulletin. Taylor Instrument Companies, Rochester, N. Y., or Toronto, Ont.

701J AC or DC Electronic Recorder

Compare these features . . . common to the 701J Electronic



1. A Taylor 'first'. On both Electronic (left) and Pneumatic (right) instruments, controller response adjustments are quickly and easily made from the front, where results can be watched. You can visualize immediately all pertinent process information — chart, pen and set-point.



2. All major components plug in. Even individual amplifier circuits plug in. You can service all components and still stay on control. AC and DC Recorders are completely transistorized; unaffected by a supply voltage change up to ±10%.

Taylor Instruments

READABILITY

instrumentation by Taylor

- **Simplest scanning of all** . . . because chart record, pen and set-point are side-by-side.
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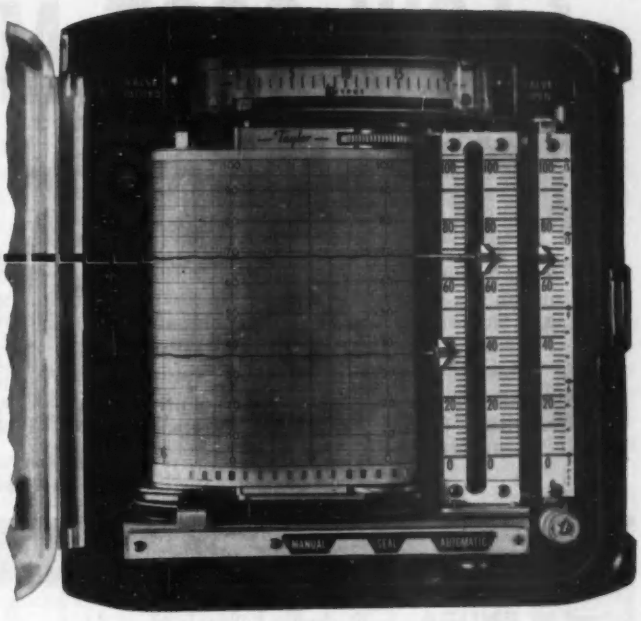
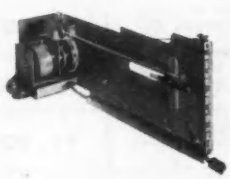
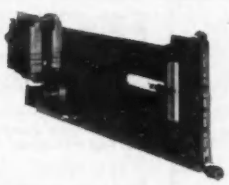


90J TRANSCOPE Pneumatic Recorder*

AC or DC Recorder and the 90J TRANSCOPE Pneumatic Recorder





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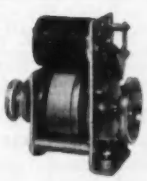

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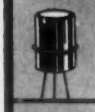
	TYPE	V_{CB} Max. (Volts)	V_{CES} Max. (Volts)	Peak I_C (Amps)	P Max. (Watts)	F b (MC)	Beta	Applications	PRICE
	**2N1124**	40	35	0.5	0.3	0.4 Min	h_{fe} 40 Min	For high voltage general purpose use in amplifier and switching. Small signal beta controlled.	**$ 1.30**
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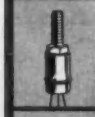	**2N1126**	40	35	0.5	1.0	0.4 Min	h_{fe} 40 Min	1 watt version of 2N1124 for servo amplifiers and relay actuators. Small signal beta controlled.	**$1.80**
	2N1127	40	40	0.5	1.0	1.0 Min	h_{FE} 50-150 @ 0.5 amp	1 watt version of 2N1125 for servo amplifiers and control systems. DC beta controlled.	**$2.40**
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Control ENGINEERING MARCH 1959

Meetings Need Editorial Themes

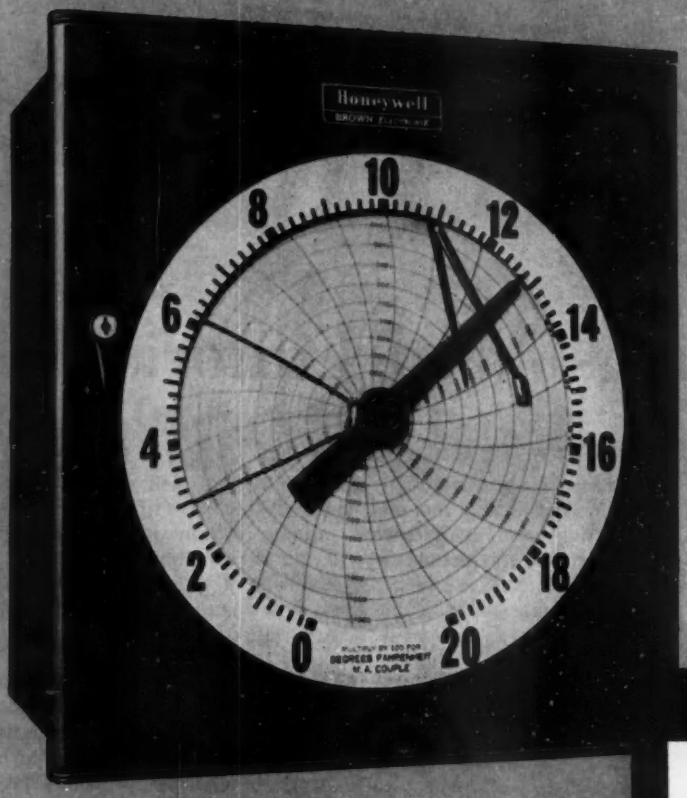
How many national technical meetings will you go to this year? Three? Six? At this very moment, you probably can put your finger on at least a dozen meetings and exhibits that promise information and displays of the utmost importance to the control field; but if you attended all of them, the cost to your company could easily be $5,000. Very few companies are willing to make this kind of investment. But then, how many are willing to invest in just one or two meetings, without a demonstration of value? The number is not much higher.

How can you guarantee the value? You can use the same selection technique that assures you maximum value from your technical-magazine subscription money. Out of the deluge of magazines that crosses his desk, a control engineer selects those whose editorial substance (technical sessions) and advertising (exhibits) consistently help him over his workaday hurdles and bring the future into clearer perspective. A meeting, like a magazine, should have a clearly recognizable editorial theme, and should present new and useful information in a straightforward manner. But many meetings, again like some magazines, thrive on disconnected rehashes of old material and on glorified new product announcements, and devote a minimum of attention to meeting the constantly changing needs of the engineer. So his decision is simple: the control engineer will read those magazines and attend those meetings that give maximum value for limited time and money.

CONTROL ENGINEERING came face to face with this problem when Dr. John E. Gibson invited us to cosponsor, with the Electrical Engineering Dept. of Purdue University, a conference on industrial control system components. We wondered: should we add another meeting to the ever-growing list? A close look at the needs of industrial control system engineers and at other scheduled meetings brought forth a firm yes. Until now, the theme of putting control system components to work in heavy industry, a proven rich one for technical journals, has not been tried by any single technical meeting. Value received will be high, for the control engineer will obtain information about solving specific component application problems he is encountering today, and suggestions on ways to solve problems he will meet in the future. Especially intriguing from an editor's viewpoint will be the direct interchange of information between competent authorities and conferees. If a point isn't covered in an article, the perplexed reader must write a letter or get on the phone; but at a meeting he has an opportunity to get his question answered immediately—and in person.

So CONTROL ENGINEERING and Purdue have added another candidate to your list of meetings. Review the titles of papers on page 31 and see how it rates on your selection barometer. We hope it's near the top.

Bryan S. Edgewood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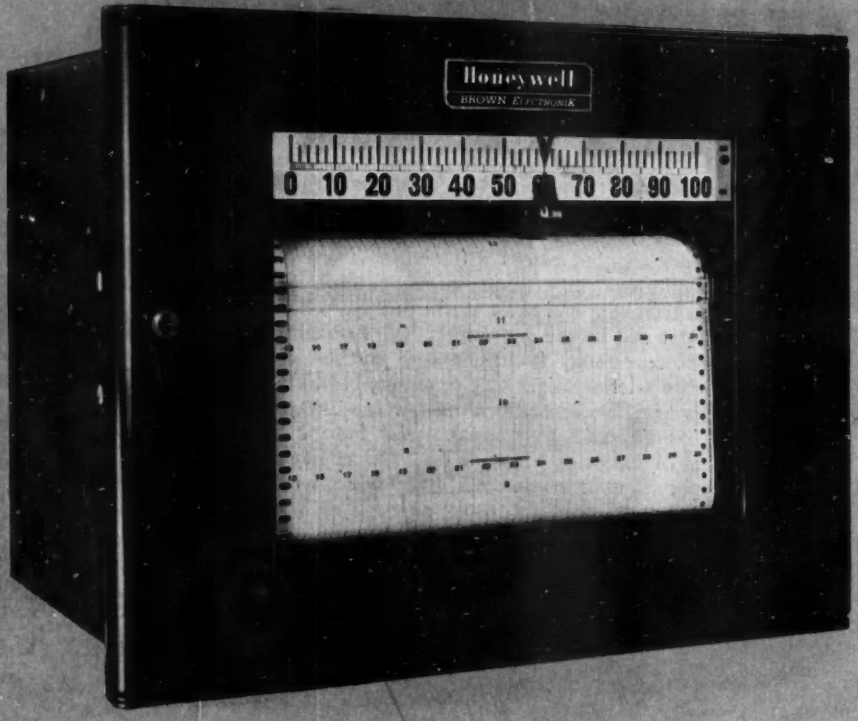
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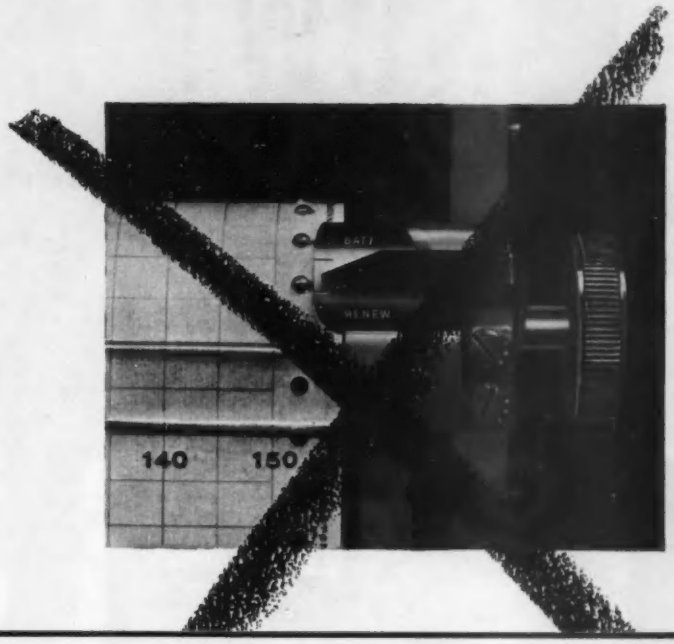

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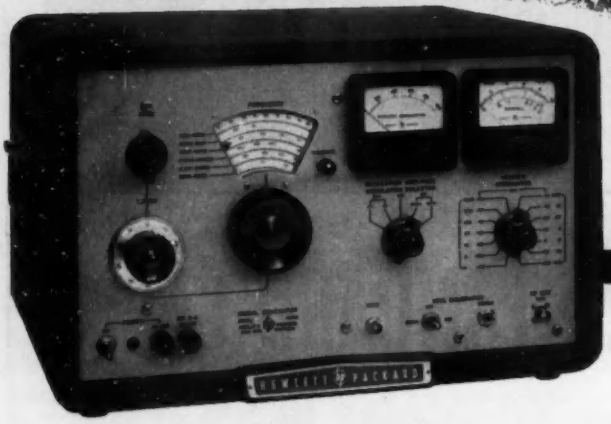

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Output Accuracy: Within ±1 db into 50 ohm resistive load.
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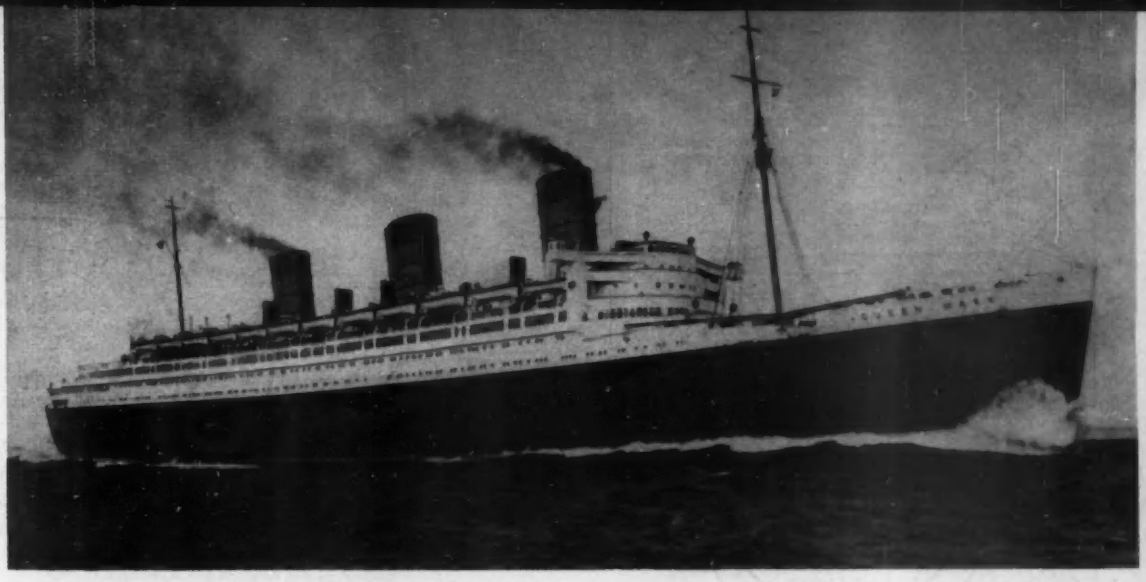


Stabilizing the Queen Mary

Controls for ship stabilizing systems are now in their third stage of development. (The first two: simple on-off control and proportional control.) New compensated control systems use roll acceleration, stabilizer fin position, and mean natural list signals to reduce roll from an unstabilized 18 deg peak to peak to less than 2 deg.

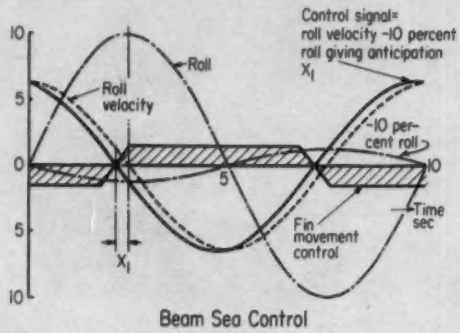
J. BELL
Muirhead & Co., Ltd., England

Control circuits for ship stabilization originated in 1938, when on-off control systems were applied to the Denny-Brown stabilizer system, in which the forward speed of the vessel gave lift to hydrofoils mounted on the side of the ship, causing a couple force in opposition to rolling motion. The on-off system operated solenoids from contacts on a velocity-sensitive gyro. This applied full fin angle and hence full stabilizing couple. While a large degree of stabilization was achieved—rolling was reduced by 70 to 90 percent—the on-off control was noisy, had excessive fin movements, and introduced an unwanted rolling motion at the fin operating frequency. Servo design was then largely empirical, and components were limited to contractors, solenoids, and 400-cps high-speed gyros; reliability naturally was low.

In stage two, development of proportional control, use was made of the fact that the residual motion of the ship, even when stabilized, was simple harmonic. The system designers realized that two different kinds of disturbances occur, the list of the ship from long period waves in a following sea, and rolling due to a beam sea. Proportional control was applied by using low-speed gyros and servos that had been designed for gunnery control. A reverse roll angle signal from the gyro gave the system anticipatory information. Figure 1 shows, for the two categories of roll, how phase advance in position was obtained by these signals. On the equipment, controls for "Following Sea" and "Beam Sea" permitted adjustment of the phase advance and smooth fin action over the fin operating range. Figure 2 shows the practical results as measured on the Royal Yacht HMY *Britannia*.

In the latest compensated controls, as now used on the *Queen Mary*, the control signal to operate the fins is made up of the acceleration function, the fin angle itself, and a natural list function that modifies the roll angle.

Ideally, only acceleration control is needed since the first result of a wave motion on the ship is an acceleration in the direction of the roll. If this were measured instantaneously and the fin angle correction applied in the opposite sense, stabilization would be achieved. But in practice a certain amount of ship motion is a prerequisite to sensing the acceleration. To make sure that this motion is of small amplitude, high sensitivity accelerometers are needed—the angular acceleration for maximum fin movement of a large vessel is only 0.30 deg/sec^2



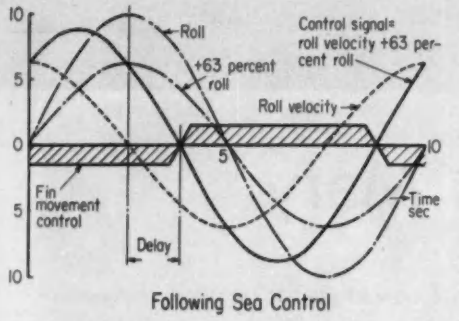


FIG. 1. Mixing roll velocity and roll angle signals in early proportional stabilizing systems gave simple anticipatory and delayed fin movement to counter both beam and following sea conditions.

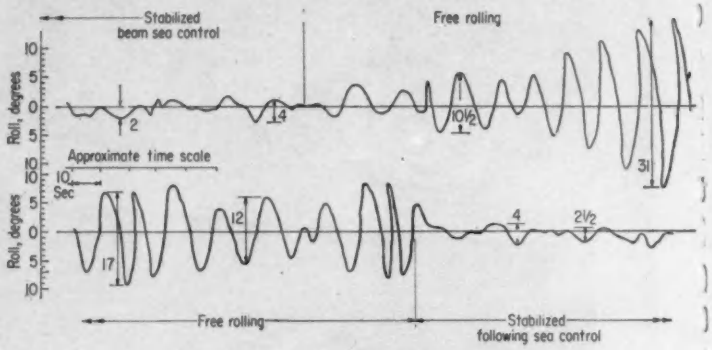


FIG. 2. Simple proportional control system installed on the Royal Yacht *Britannia* checked rolling from peak-to-peak amplitudes of 31 deg down to a maximum of 4 deg.

and control must begin at 5 percent of this value.

To avoid electronics, the present compensation control system uses a differential lever system incorporating a spring and damping unit. The lever system is coupled to the velocity gyro to give a 5:1 magnification to the movement of the acceleration synchro compared with that applied to the velocity synchro. Thus initially, for a very small ship movement the fins are operated by the acceleration function and further movement of the vessel, if of a periodic nature, gives true differentiation; the acceleration signal is 90 deg ahead of roll velocity.

Figure 3 illustrates the mechanical arrangement that produces the acceleration signal. A velocity-sensitive gyro, spring-controlled in the normal way, is mechanically coupled to a synchro generating a signal $\dot{\theta}$. One end of the main differential link attached to the velocity gyro is secured to a coupling operating a gear sector. This rotates a damping disc running under the poles of a permanent magnet. A pivoted spring-loaded lever supports the other end of lever *D*, a pivoted lever attached by further linkage to the acceleration synchro $\ddot{\theta}$. If an acceleration is suddenly imposed upon the ship, the gyro deflects instantaneously and the lower end of the lever *D* can be regarded as fixed. The upper end yields, being restrained only by a spring, and the acceleration synchro receives the full displacement signal. For conditions of zero acceleration (constant velocity) the velocity gyro takes up its deflected position and in a comparatively short time the damping disc spins, releasing the tension of the acceleration springs so that the acceleration synchro transmits zero signal again.

Control from acceleration alone would result in the fins returning to their control position when the acceleration is neutralized by fin torque; a feedback signal proportional to fin movement therefore maintains the fins in the present deflected position, and they oppose the sea force until the sea force changes. This feedback factor is variable. Complete balance is attained when it is unity; but if it is less than unity, the fins will have a tendency to creep back to their zero position. In practice a

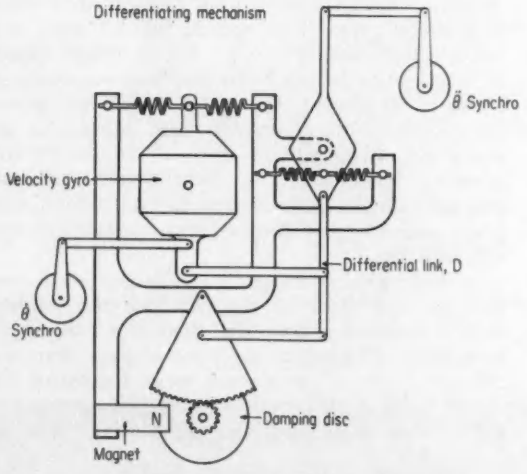


FIG. 3. In compensated control, a mechanical differentiating system operating from a rate gyro provides the acceleration signal.

feedback factor of 0.7 set up during ship trials gives the best practical results. The signal operative is written as

$$S = W - F + KF \qquad (1)$$

where W is the sea couple, and F the fin couple acting on the ship.

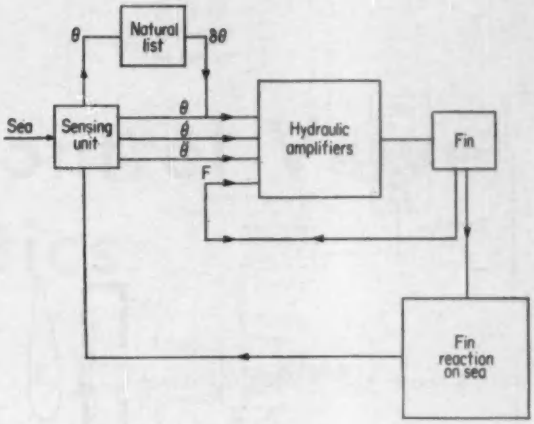
The other addition to the control system mentioned above is the natural list function. This operates from the vertical gyroscope and consists of a servo follow-up unit with a long time constant. The unit follows the roll angle generated, but with the time constant at least 10 times longer than the rolling period. The output of the servo therefore settles down to the mean center of rolling and the vessel stabilizes about this mean center. This reduces drag—stabilizing power is not used to counter lists due to wind, cargo movement, or fuel consumed—and so is economically attractive. If desired, the natural list control can be switched out.

Control of the stabilizer is vested, therefore, in five functions: roll, roll velocity, roll acceleration, fin feedback, and natural list. The whole control signal may be written in simplified form

$$S + K_1\theta + K_2\dot{\theta} + K_3\ddot{\theta} + K_4F \qquad (2)$$

where K_1 to K_4 are multipliers, constants, time constants, delays, and limits appropriate to each function; $\ddot{\theta}$ is $W - F$ of Equation 1, and θ is the roll angle corrected for natural list.

Figure 4 shows the signals and the closed loops involved. The sensing unit provides the roll, the roll velocity, and roll acceleration signals, the roll signal being modified by a small roll angle inserted by the natural list generator. These three signals



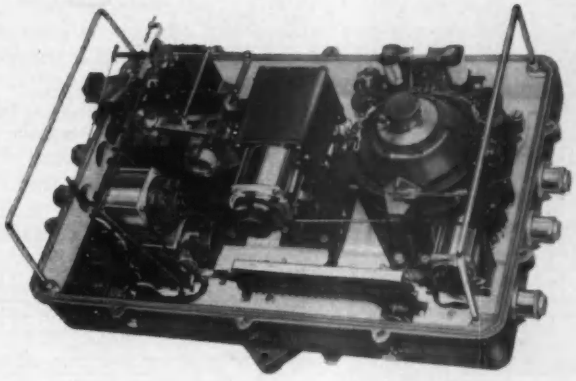


FIG. 4. A—Two closed loops make up the compensated control system. B—The acceleration linkage is mounted above the velocity gyro (left); the roll angle gyro is on the right.

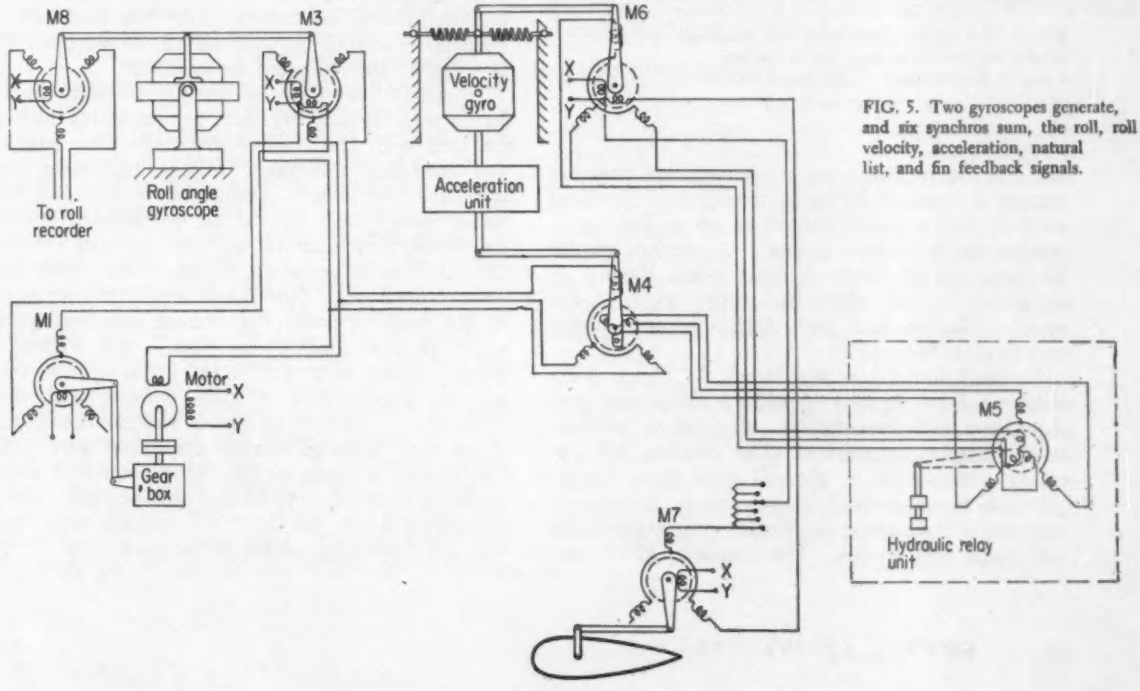


FIG. 5. Two gyroscopes generate, and six synchros sum, the roll, roll velocity, acceleration, natural list, and fin feedback signals.

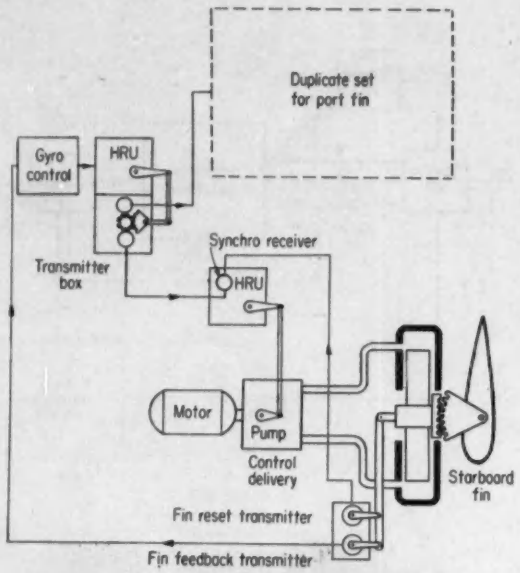


FIG. 6. In the *Queen Mary* installation, a synchro transmitter on each fin controls output to the hydraulic relay, reducing the hydraulic pump delivery to zero when fin movement is complete.

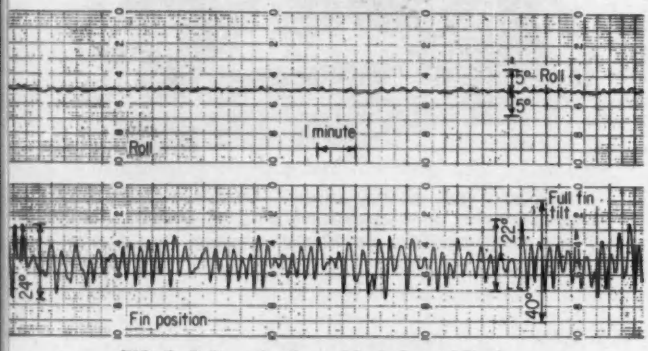


FIG. 7. Roll on the *Queen Mary's* first stabilized crossing was reduced in rough seas to less than 2 deg by fin movements of less than ¼ maximum.

and the fin feedback are combined, and together operate a series of hydraulic amplifiers. The final amplifier has a power output of up to 100 hp to actuate the fin operating rams. A synchro on the fin gives the fin feedback signal while the fin reaction on the sea alters the rolling angle of the vessel. This in turn feeds back into the sensing unit to close the loop.

Figure 5 shows how the signals in Figure 4 are obtained from receiver synchros, differential synchros, and two-phase resolver synchros in addition to the normal transmitters. The synchro M3, operated mechanically by the roll angle gyro, is energized on terminals X Y from a 50-cps supply and produces a three-phase positional control signal for differential synchro M4. The output of M4 is controlled mechanically by acceleration, giving direct addition of the angle and angular acceleration, $\theta + \ddot{\theta}$.

In the natural list unit a two-phase motor is energized on one phase from the main supply. When the synchro M3 departs from zero the motor rotates in one direction or the other. Synchro M1 is coupled to the motor through a large reduction gearbox, and acts as an induction regulator. When it is driven away from zero, current flows in the cross winding of resolver synchro M3. This alters the position of the magnetic field tending to bring M3 to its zero position, and the natural list unit runs until zero signal is obtained on the motor, determining the mean listed position of the vessel.

The synchro M6 is coupled to the velocity gyro, and it and the synchro M4 operate synchro receiver M5, which controls the hydraulic relay unit from which the fins are actuated. The synchro M7 is coupled mechanically to the fin and operates through a potentiometer on the rotor of M6 similar to the way the synchro M1 acts on M3. The potentiometer regulates the fin feedback signal, and a potentiometer in the output circuit of synchro M1 alters the natural list effect.

Figure 6 shows diagrammatically the practical layout of the system recently installed on the 81,000-ton *Queen Mary*. Besides the controls already described, another synchro control is also used in the high-powered servo operating the fin. The synchro output of the first hydraulic relay unit (HRU) operates a pair of transmitters, each of which controls a further HRU, one for the port fin and the other for the starboard fin. Each HRU in turn controls the output of a variable delivery pump which directly operates the fin rams. A transmitter coupled to the fin resets the HRU and consequently sets the pump delivery to zero when the fin has executed the movement required. The fin feedback transmitter feeding the gyro unit is also mechanically attached to the starboard fin as shown.

Because initial trials of the *Queen Mary* installation were in calm weather, forced rolling had to be used with the control reversed. One pair of fins generated the forced rolling, the other pair stabilized the vessel. Using the fins to roll the vessel would have created an unstabilized rolling amplitude of at least 18 deg peak to peak. With the stabilizer in operation, however, the rolling was reduced to 2 deg. No comparison could be made at the trials between free rolling and stabilizing under normal running conditions, but Figure 7 shows a record of both ship and fin movement during the vessel's first Atlantic crossing with the stabilizers. The full fin power was not employed at any time, although weather conditions were quite rough and it is estimated that an uncontrolled vessel would have rolled up to 20 deg peak to peak. From the record it can be seen that roll was kept well within 2 deg—indiscernible to the passengers.

A fresh look at Selecting Control Valve Characteristics

Choosing the right valve characteristic is a matter of utmost importance in many processes, especially those needing close, stable control and having small holdup times. The author has organized a set of rules that readily enables the control engineer to select the best valve characteristic with respect to the static and dynamic effects of the disturbing variables. His article traces the development of the selection rules—grouped in a handy table for future reference and use—and concludes by showing how to determine the best valve characteristic for four types of recurring proces control problems.

JAKE E. VALSTAR, C. F. Braun & Co.*

A satisfactory control system must fulfill certain objectives of stability, speed of response, and accuracy. Unhappily, these objectives are conflicting, since stability requires a loop gain less than unity at a frequency with 180-deg loop phase shift, while speed of response and accuracy require a high loop gain at all frequencies. Still, certain steps can be taken to improve control. One step is to adjust some of the static and dynamic properties of the control loop by changing proportional band, reset, and rate controller actions. However, a change in operating point affects both the static and dynamic properties of the controlled system—the process and its control valve—so that controller settings are not adequate for all situations. Control can become fast but unstable for some conditions or sluggish but stable for others. The best compromise must be found, and this can be done by a second step—selection of the best valve characteristic to help improve static and dynamic control.

Variations in the controlled system's operating point occur because the process is subject to disturbances and because the control valve counteracts these disturbances by exerting corrective action on the manipulated variable. Variations in static gain arise through a change to a new operating point. Dynamic properties are affected because a change in the value of the manipulated variables may, in turn, change the time constants of the process. Which valve characteristic to use depends primarily on the sources of disturbances and the effect they have on the static and dynamic gains of the process.

The control valve gain, the slope of the valve characteristic at the operating point, should be chosen to maintain the loop gain (at 180-deg loop phase shift) constant. That is, the control valve gain should be the inverse of the process gain over the full range of operating points. The process gain is the ratio of a small variation in controlled variable, at any operating point, to a small variation in manipulated variable at the same operating point.

Since a process may be subject to many different disturbances, each of which may change the process static and dynamic properties in a different way, each disturbance may call for a different valve characteristic. But in general only one valve, and hence only one characteristic, will be used in a control loop. Conflicting requirements, if any, must then be resolved in favor of the valve characteristic that best compensates for disturbances.

Valve characteristics

Figure 1 graphs the four basic valve characteristics: square-root, linear, equal-percentage (or exponential), and hyperbolic; the mathematical descriptions of their gain and characteristic are shown in Table I. The characteristics are given for the valve without actuator. The valve actuator's stem-position-to-controller-output relation and dynamic gain are assumed constant. Two of the four characteristics, the linear and the equal-percentage, are available on the market as linear and equal-percentage valves.

There is an important distinction to be made at this point. Commercially available valves exhibit linear or equal-percentage characteristics only when the pressure drop over the valve plug itself is constant. From now on, the expressions *linear valve* and *equal-percentage valve* will be used when the valve itself is meant. The expressions *linear char-*

* Now with Hughes Aircraft Co.

TABLE I — VALVE CHARACTERISTIC AND GAIN

1) SQUARE-ROOT

A small variation in stem positions gives a small variation in flow F, which is proportional to stem-position variation and inversely proportional to flow.

$$d(F/F_{max})/dS = k/(F/F_{max}) \quad \text{(Gain)} \quad (1)$$

$$\int (F/F_{max})\, d(F/F_{max}) = \int k\, dS$$

$$(F/F_{max})^2/2 = kS + k_1$$

The values of k and k_1 are chosen so that $F/F_{max} = 0$ when $S = 0$ and $F/F_{max} = 1$ when $S = 1$. Thus,

$$F/F_{max} = \sqrt{S} \quad \text{(Characteristic)} \quad (2)$$

2) LINEAR

A small variation in stem position gives a small variation in flow, which is proportional to stem-position variation and independent of flow.

$$d(F/F_{max})/dS = k \quad \text{(Gain)} \quad (3)$$

$$\int (F/F_{max}) = \int k\, dS$$

$$F/F_{max} = kS + k_1$$

The values of k and k_1 are chosen so that $F/F_{max} = 0$ when $S = 0$ and $F/F_{max} = 1$ when $S = 1$. Thus,

$$F/F_{max} = S \quad \text{(Characteristic)} \quad (4)$$

3) EXPONENTIAL OR EQUAL-PERCENTAGE

A small variation in stem position gives a small variation in flow, which is proportional to stem-position variation and to flow.

$$d(F/F_{max})/dS = k(F/F_{max}) \quad \text{(Gain)} \quad (5)$$

$$\int (F/F_{max})^{-1} d(F/F_{max}) = \int k\, dS$$

$$\ln k_1 (F/F_{max}) = kS$$

$$F/F_{max} = e^{kS}/k_1$$

The values of k and k_1 are chosen so that $F/F_{max} = 0.02$ when $S = 0$ and $F/F_{max} = 1$ when $S = 1$. Thus,

$$F/F_{max} = 0.02 \times 50^S \quad \text{(Characteristic)} \quad (6)$$

4) HYPERBOLIC

A small variation in stem position gives a small variation in flow, which is proportional to stem-position variation and to the square of the flow.

$$d(F/F_{max})/dS = k(F/F_{max})^2 \quad \text{(Gain)} \quad (7)$$

$$\int (F/F_{max})^{-2} d(F/F_{max}) = \int k\, dS$$

$$-(F/F_{max})^{-1} = kS + k_1$$

The values of k and k_1 are chosen so that $F/F_{max} = 0.02$ when $S = 0$ and $F/F_{max} = 1$ when $S = 1$. Thus,

$$F/F_{max} = 1/(50 - 49\,S) \quad \text{(Characteristic)} \quad (8)$$

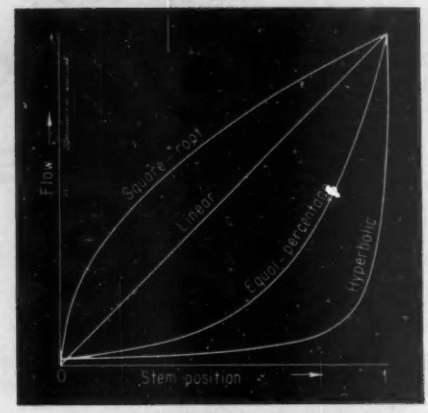


FIG. 1. Ideal valve characteristics.

acteristic and equal-percentage characteristic will be used when the flow characteristic of a valve-plus piping combination is meant.

Basing the Valve Characteristic on Static Considerations

The value of the controlled variable depends on the values of other process variables, one of which is the manipulated variable. Some variables cannot be used as the manipulated variable because they might interfere with another control loop or because they are just plain impossible. A look at the temperature control system in Figure 2 explains why.

The output temperature, the controlled variable, depends on the flow of the fluid to be heated, the input temperature of the fluid, the flow of the fuel, the heat of combustion of the fuel, and indirectly the fuel pressure. Here, using the fuel flow as the manipulated variable is logical since the controlled variable is sensitive to fuel-flow changes and controlling flow is easy. When the value of one of the other variables changes, the controller adjusts the manipulated variable, via the control valve, in such a way that the controlled variable is kept at its desired value. The other variables are called disturbing variables, and variations in their values are called disturbances.

If there are no disturbing variables, or no (or very small) disturbances, the manipulated variable and the control valve remain at one specific operating point and the control valve characteristic is of no importance. The control valve has a certain constant gain and the setting of the controller's proportional band establishes the proper loop gain. No change will occur. (In fact, under this ideal condition of no disturbances, no control system would be needed.)

Practically, though, the controlled variable can be influenced by disturbing variables in two ways: When the disturbing variables are considered one at a time, each one, together with the manipulated variable, are seen to contribute an effect to the controlled variable. If the total contribution disappears when the manipulated variable is made zero, the two contributions can be said to *multiply*. They can be said to *add* if the contribution of the disturbing variable remains when the manipulated variable is made zero. In the example of furnace temperature control, Figure 2, the fuel flow can be made zero. Then variations in fluid flow, fluid specific heat, fuel heat of combustion, and fuel pressure will no longer have any influence on the output temperature, but input temperature will have an influence because now the output temperature is always the same as the input temperature.

Disturbing variables can be divided into four groups:

▶ *Group 1* is composed of disturbing variables of an adding nature, there being a linear relation between the manipulated variable and its contribu-

tion to the controlled variable. (In the example of the furnace with temperature control, it is the heated fluid's input temperature.) The manipulated variable has to change to counteract such disturbances, and a variation of a certain magnitude always causes a variation in the controlled variable proportional (or linear) to that magnitude. This means that here a linear valve-plus-line characteristic is needed to change the controlled variable by a certain amount for a certain change in stem position, whatever the value of the manipulated variable might be. In this way, the static gain from the control valve to the controlled variable is kept constant.

▶Group 2 is composed of disturbing variables of an adding nature, the relation between the manipulated variable and its contribution to the controlled variable being quadratic, as in controlling fluid flow and pressure: $\Delta P = KF^2$. The manipulated variable has to change to counteract such disturbances. For a quadratic relationship, a variation of a certain magnitude in the manipulated variable causes a variation in the controlled variable proportional to that magnitude and to the manipulated variable. Now a square-root valve-plus-line characteristic is needed to keep the static gain constant.

▶Group 3 is composed of disturbing variables of the multiplying nature that do not enter the process by influencing the manipulated variable. (In the example they are the flow of fluid to be heated, its specific heat, and the heat of combustion of the fuel.) The manipulated variable has to change to counteract such disturbances. Variations of a certain percentage in the manipulated variable cause a variation in the controlled variable proportional to that percentage. Here, an equal-percentage valve-plus-line characteristic is needed to vary the controlled variable by a certain amount for a certain change in stem position, independent of the value of the manipulated variable. In this way, again the static gain is kept constant.

▶Group 4 is composed of those variables of the multiplying nature that do enter the process by influencing the manipulated variable. (In the example it is the fuel pressure.) The corrective action of the control valve against disturbances of this group has to be such that the manipulated variable itself is kept constant. The manipulated variable itself is now the controlled variable. The same circumstances exist in flow control, where the controlled variable is also directly or indirectly the flow through the control valve. In these cases, the real manipulated variable is the valve-port opening, and an equal-percentage valve (not valve-plus-line characteristic) is needed to vary the controlled variable by a certain amount for a certain stem position. In this way, the static gain is kept constant.

The disturbing variables and the valve characteristic to use are listed in Table II, Part A. This table also shows selection based on dynamic considerations.

Basing the Valve Characteristic on Dynamic Considerations

Figure 3 shows how loop gain can vary due to a change in static loop gain or to a change in process dynamic properties. A combination of the two can also change the gain. Up to now, the characteristic was chosen with an eye to keeping the static loop gain constant in spite of disturbances. These same disturbances, however, may also affect process dynamic properties, thereby changing the gain at 180-deg phase lag. But keeping the loop gain constant at 180-deg phase lag by using the proper valve characteristic would give one setting of controller proportional band control over the whole range.

The procedure is to see how the process gain at 180-deg loop phase lag varies with changes in dynamic properties, and then to choose a valve characteristic (taking into account the characteristic previously chosen from static considerations) that keeps the gain constant at 180-deg phase lag. In most cases, the manipulated variable is basically a material or heat flow, and the dynamic properties then are always in some way dependent on the manipulated variables. The procedure can be established separately for two types of processes: those having only one time constant dependent on the manipulated flow and those having more than one time constant dependent on the manipulated flow. The single (flow-dependent) time constant process

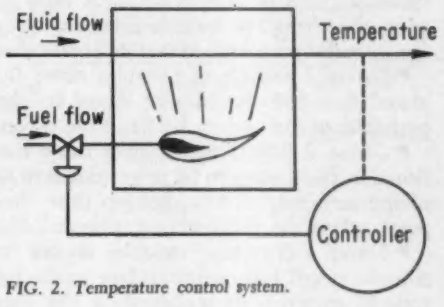


FIG. 2. Temperature control system.

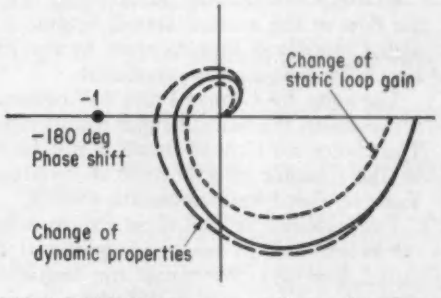


FIG. 3. Typical frequency response diagram shows how the static loop gain and the gain at 180-deg phase lag can both change when the manipulated flow changes.

arises most frequently in practical applications. Here, as will be shown, the valve characteristic to use for a particular disturbing variable can be related, like the choice on static considerations, directly to the disturbing variable. But multitime-constant processes may have one time constant dependent both on the manipulated flow and on a disturbing variable, so that one time constant may remain fixed while the others change with variations in the manipulated flow. For such processes the procedure is complicated but does permit an orderly choice.

Single-time-constant processes

When a material or heat flow enters a process, it has to leave at some other place. In between, the process has a certain storage capacity for the material or heat. It is common usage, when the storage capacity is concentrated in one place, to speak about the *holdup time* of the process. The holdup time is the quantity of material or heat stored, divided by the flow of material or heat. If the flow influences the stored quantity and vice versa, the holdup time determines one (often the largest) time constant of the process. There may be other (nonflow-dependent) time constants in the process, such as measuring and transmission lags.

In most cases, the material or heat flow is in some way dependent on the manipulated variable and the controlled variable in some way dependent on material or heat flow *and* on the amount stored. Thus, the holdup time (for a concentrated storage) is related to changes in the manipulated and controlled variables and, since the specific relation between these variables is defined for each type of disturbance, the change in holdup time can be related to the disturbing variable in one of these groups:

▶ Group 1 disturbing variables cause the manipulated flow and the amount stored to change proportional to each other; holdup time is constant.

▶ Group 2 disturbing variables cause the amount stored in the process to be proportional to the square of the manipulated flow; holdup time changes proportional to the manipulated variable.

▶ Group 3 disturbing variables do not change the amount stored but cause the flow to change; holdup time is inversely proportional to the manipulated variable.

▶ Group 4 disturbing variables do not influence the flow or the amount stored, because the manipulated variable is kept constant by the control system; holdup time remains constant.

The valve for Groups 1 and 4 disturbing variables is chosen on the basis of static considerations alone. The choice for Groups 2 and 3 will be influenced by the dynamic effect of the disturbing variables. Table II, Part B summarizes the choices.

The reasoning behind these choices follows:

▶ When holdup time is proportional to manipulated flow and determines the largest time constant, the process gain at 180-phase lag is inversely proportional to flow.

▶ When holdup time is inversely proportional to manipulated flow and determines the largest time stant, the process gain at 180-deg phase lag is inversely proportional to flow.

Group 2 disturbing variables cause the static gain to vary proportional to the manipulated flow. But they also cause the time constant to vary proportional to the flow. The net result is that, for a single holdup time process, a Group 2 disturbing variable causes the gain to remain constant with changes in the manipulated flow. Thus, a linear valve-plus-line characteristic is used.

Group 3 disturbing variables cause the static gain to vary inversely proportional to the manipulated flow. They also cause the time constant to vary inversely proportional to the flow. Again, the net result is that, for a single holdup time process, a Group 3 disturbing variable causes the process gain to remain constant with changes in the manipulated variable. And again a linear valve-plus-line characteristic is used.

Multitime-constant processes

Choice of the correct valve characteristic for multitime-constant processses can be related to a type of disturbing variable but sometimes only indirectly because, as was mentioned previously, such a disturbance and the manipulated variable may both affect one time constant in opposite directions; then the critical time constant will not change, while the other time constants will change because of the change in the manipulated flow alone.

For each disturbing variable, each time constant must be analyzed to see what effect a change in the manipulated flow has on it, and then all must be analyzed to see how the loop gain at 180-deg loop phase lag varies according to the manipulated flow. The effects can be divided into three categories:

1. The loop gain at 180-deg loop phase lag varies proportional to the manipulated flow. Here, the valve compensates by letting the static loop gain vary inversely proportional to the flow. As in the single-time-constant process, some of this compensation comes from the characteristic selected on static considerations, so the final choice, accounting for both static and dynamic considerations, depends on the original static choice. Table II, Part C, points out which valve characteristic to use.

2. The loop gain at 180-deg loop phase lag varies inversely proportional to the manipulated flow. Here, the valve compensates by letting the static loop gain vary proportional to the flow. The valve characteristic to use is shown in Table II, Part C.

3. The loop gain at 180-deg loop phase lag remains constant with changes in the manipulated flow. Here, the valve characteristic to use depends only on the static choice, and this, too, is shown in Table II, Part C.

Under what conditions does a multitime-constant process show these three effects? The answers were obtained for a four-time-constant process by plotting

families of curves, showing how the manipulated flow varies the time constants and how these variations affect the loop gain at 180-deg loop phase lag. Here the first time constant is the largest, the second is the next largest, and so on. Several families of curves were plotted; in one three time constants were held fixed (at several different values) and the fourth varied over a range of 10^8; in another two time constants were held fixed and two varied; and in a third three time constants were varied and one held fixed. The answers are listed in Table II, Part D. The specific effect for a disturbance to a given process is referred back to Part C. Also a dead time was introduced. It was found that time constants smaller than the dead time have no influence on the loop gain at 180-deg loop phase lag.

It is important at this point to summarize and emphasize the procedure:

1. The process is analyzed to determine, on a qualitative basis, the disturbing variables that can affect the controlled variable.

2. The valve characteristic is determined for each disturbing variable and the estimated size (quantitative basis) of the disturbance determines the dominance of that characteristic in making the final selection of the control valve.

3. The control valve is finally selected on the compromise basis of the dominating characteristic needed to compensate for all disturbing variables.

It must be noted that the valve characteristic can compensate for variations in gain only. The frequency at 180-deg phase lag varies, too, and these variations can give difficulties with the settings for reset and rate actions.

It is also possible that the stored amount does not influence the flow, as in a level control system in which the change in level is negligible or the static pressure in the vessel is high. The material stored will now be the integral of the difference between the incoming and the outgoing flows. When this difference is zero, the level remains constant. When not zero, it will increase or decrease at a constant rate proportional to the difference. The dynamic properties of such a process without self-regulation do not change as a function of the flow. If one of the flows is a disturbing variable, it belongs to Group 1 and requires a linear characteristic.

When equally strong disturbances cause troublesome conflicting requirements in making the valve selection, one of the disturbing variables can be eliminated by maintaining it constant with its own control system or, in the case of a Group 4 disturbing variable, with a master-and-slave control system.

For selection examples, turn the page

TABLE II – HOW TO CHOOSE THE BEST VALVE CHARACTERISTIC

DISTURBING VARIABLE	STATIC CONSIDERATIONS PART A	DYNAMIC CONSIDERATIONS			
		Single holdup time PART B	Multiple-time-constant process PART C		
			Loop gain* varies proportional to manipulated flow	Loop gain* varies inversely prop. to manipulated flow	Loop gain* is constant
GROUP 1 (adding, linear)	Use linear valve-plus-line characteristic	Same as static	Use square-root characteristic	Use equal-percentage characteristic	Same as static
GROUP 2 (adding, quadratic)	Use square-root valve-plus-line characteristic	Use linear characteristic	–	Use linear characteristic	Same as static
GROUP 3 (multiplying, no influence on manipulated variable)	Use equal-percentage valve-plus-line characteristic	Use linear characteristic	Use linear characteristic	Use hyperbolic characteristic	Same as static
GROUP 4 (multiplying, influences manip. var.)	Use equal-percentage valve	Same as static	–	–	–

*At 180-deg loop phase shift.

PART D – HOW MANIPULATED FLOW AFFECTS PROCESS GAIN

1. The process gain at 180-deg phase lag is proportional to the manipulated flow when:
   a. The largest time constant† (being much larger than the other time constants) is inversely proportional to the flow; or
   b. The two largest time constants (being much larger than the other time constants) are inversely proportional to the flow; or
   c. The third time constant (with or without smaller time constants and being much larger than the next smaller independent time constant) is proportional to the flow; or
   d. The second, third, and fourth time constants with or without smaller time constants are proportional to the flow.

2. The process gain at 180-deg phase lag is constant when:
   a. The second time constant is dependent on the flow; or
   b. The fourth or smaller time constants are dependent on the flow; or
   c. The second and third time constants are dependent on the flow, the difference between the first and fourth being not too large; or
   d. The first, second, and third time constants are dependent on the flow; or
   e. The dependent time constants are smaller than the dead time.

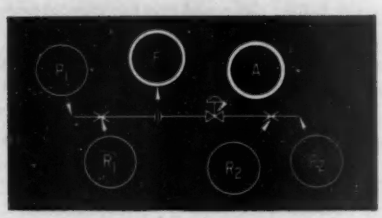
3. The process gain at 180-deg phase lag is inversely proportional to the manipulated flow when:
   a. The largest time constant (being much larger than the other time constants) is proportional to the flow; or
   b. The two largest time constants (being much smaller than the other time constants) are proportional to the flow.
   c. The third time constant (with or without larger time constants and being much larger than the next smaller independent time constant) is inversely proportional to the flow; or
   d. The second, third, and fourth time constants, with or without smaller time constants, are inversely proportional to the flow.

†The time constants are counted in order of magnitude, the first one being the largest.

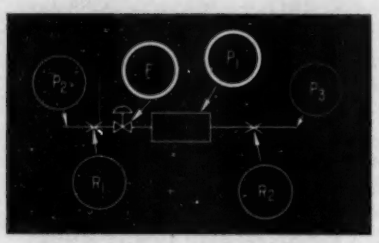
Four Practical Examples in Choosing a Control Valve Characteristic

EXAMPLE 1–FLOW

Controlled variable: Flow F (direction not specified)
Manipulated variable: Valve port area A
Disturbing variables: Pressure P_1
Pressure P_2
Resistance in line or equipment R_1
Resistance in line or equipment R_2



When making the manipulated variable zero (by closing the valve) the controlled variable F becomes zero too, and none of the disturbing variables has any influence. They are Group 3 disturbing variables and call for an equal-percentage valve in all cases, keeping in mind that the manipulating variable is the valve port area. No time constant is dependent on the manipulated variable.



EXAMPLE 2–PRESSURE

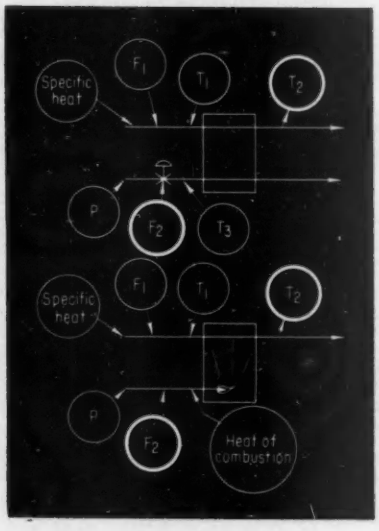
The pressure is controlled in a vessel with an incoming material-flow and an outgoing material-flow.

Controlled variable: Pressure P_1
Manipulating variable: Flow F (direction not specified)
Disturbing variables: Pressures P_2 and P_3
Resistances R_1 and R_2

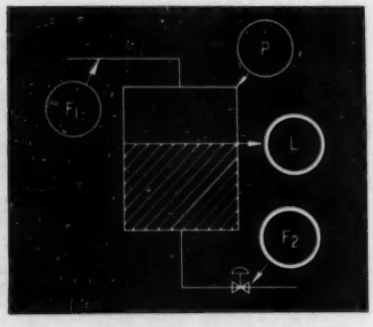
When the manipulating flow is made zero, the disturbing variables P_3, R_1, and R_2 do not influence P_1. They are of the multiplying type. P_2 and R_1 (Group 4) require an equal-percentage valve, because if only these give two disturbances, F is in fact controlled. R_2 (Group 3) requires an equal-percentage characteristic of the valve-plus-line-and-equipment at the controlling-flow side. P_3 (Group 2) can still influence P_1 if F is zero and requires, in this case, a square-root characteristic; if the holdup time of the vessel determines the largest time constant, a linear characteristic must be used instead of the equal-percentage or the square-root.

EXAMPLE 3–TEMPERATURE

Controlled variable: Temperature T_2
Manipulated variable: Fuel flow F_2
Disturbing variables: Fluid flow F_1
Input temperature T_1
Specified heat (composition) of F_1
Pressure P
Heat of combustion (fuel quality)
Input temperature T_3



If the manipulated flow F_2 is zero, the only disturbing variable able to influence T_2 is the input temperature T_1. This Group 1 disturbing variable requires a linear characteristic. All the other ones (Group 3) require equal-percentage characteristics, except P (Group 4) which requires an equal-percentage valve. Flow F_2 may be steam that condenses or a liquid that flashes in the heat exchanger. If flow F_1 condenses or flashes, the influence of variations in T_1 is minor, but the heat of vaporization (composition) becomes important. If the first time constant is dependent on manipulated flow, a linear characteristic shall be used instead of an equal-percentage.



EXAMPLE 4–LEVEL

Controlled variable: Level L
Manipulated variable: Flow F_2
Disturbing variable: Flow F_1
Pressure P

If the manipulated flow is made zero, the level changes due to F_1 (Group 1). This requires a linear characteristic. If P (Group 4) has influence on manipulated flow F_2, an equal-percentage valve is required. If P has influence on the nonmanipulated flow F_1, and in this way indirectly on the level, P is a Group 1 disturbing variable requiring a linear characteristic.

How Diodes Generate Functions

THE GIST: Here is a description of the basic diode-resistor voltage-sensitive networks, leading to a universal diode function generator circuit. Practical diode-biasing techniques are also developed. A later article will detail the effects of actual nonideal diode characteristics on these networks, and will discuss the basic circuits used in the most important commercially available universal diode function generators.

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The theory of diode function generators is based on the fact that abrupt changes in circuit impedance occur when biased diodes switch from conduction to nonconduction, or vice versa. The point of conduction of a diode in a resistance network can be controlled by biasing, and the number and the sequence of diodes that conduct can be made dependent on the magnitude and sign of the voltage input to the network. In this manner, the input-output transfer characteristic of the network may be made to approximate any desired continuous function by a series of linear segments.

With functions consisting of only a few linear segments, such as backlash, dead-zone, and saturation characteristics, only a few diodes are necessary. The generation of smooth curves, on the other hand, requires small incremental changes of circuit impedance, and the original function can be closely approximated only if a large number of diodes are used. The number necessary will depend on the function and the desired accuracy.

The nonlinear nature of actual diode characteristics makes transition to the conduction state gradual, rather than ideally abrupt. When generating functions by linear approximation, this effect causes slightly rounded transitions from one segment to another. The amount of curvature depends on the diodes used. Silicon junction diodes give sharper breaks than thermionic types. The amount of curvature is usually negligible when functions with slope discontinuities are generated, and for smooth functons a slight curvature is desirable.

In the circuits to follow, the equations presented assume ideal diodes. The effects of the nonideal nature of actual diodes will be discussed later.

Basic circuits

The resistance of a biased-diode-resistor network may be designed to be a discontinuous (step-wise) function of driving voltage or driving current. The voltage-current characteristic of the network then becomes a monotonic nonlinear function composed of linear segments. As an example, the circuit of Figure 1A is made up of a parallel arrangement of a resistor, R_0, and any number of biased-diode and resistor combinations. Assuming $E_1 < E_2$, etc., the dynamic input resistance of the network is the slope, $\triangle E/\triangle I$, of the E vs. I characteristic of the network. This is the discontinuous function of input voltage shown in Figure 1B. Figure 1C is the curve of input current vs. input voltage—a monotonic function.

In general, for the circuit of Figure 1A, the slope of the I vs. E characteristic, or the dynamic input conductance, is given by

$$\sum_{k=0}^{i} \frac{1}{R_k}$$

Such a network may also include any number of resistor-diode-battery circuits of the opposite polarity, in which case a similar monotonic relationship of I vs. E will be obtained for negative values of E.

As another example, Figure 2A is the dual of the network of Figure 1A. If $E_1/R_1 < E_2/R_2$, etc., the dynamic resistance of the network will depend on the input current in the step-wise manner shown by Figure 2B, while the input-voltage, input-current characteristic has the monotonic form of Figure 2C. At any value of I, the slope of the E vs. I characteristic is equal to the dynamic input resistance.

These simple nonlinear networks are used in many ways to generate functions. One popular design embodies the circuit of Figure 1A with an additional resistance in series with the input, and R_0 serving as the load resistance . If R_0 is constant, such a network can generate monotonic functions in the first and third quadrants directly, and in the second and fourth quadrants if an inverter stage is used.

Why use amplifiers?

Operational amplifiers allow more freedom to the designer of diode-function-generator networks by providing the possibiltes of sign inversion and summation, as well as amplification. Multitonic functions (those in which the slope may change sign)

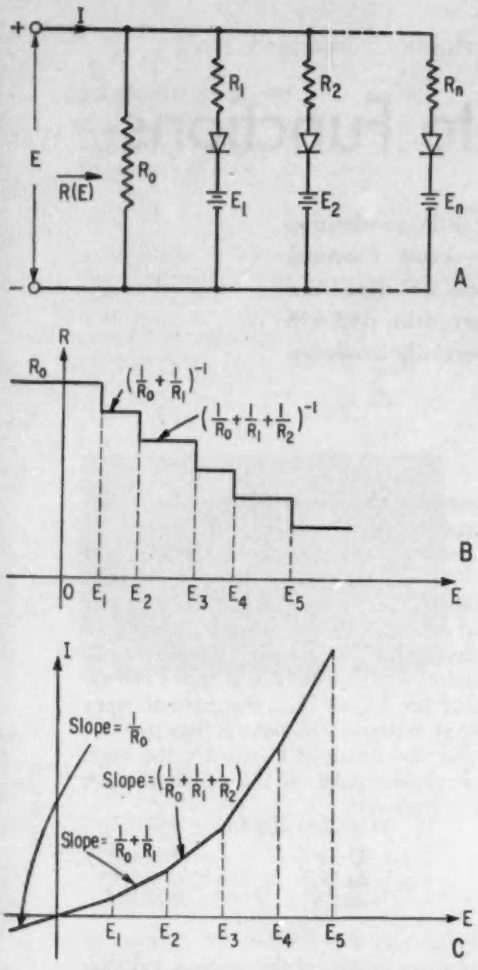


FIG. 1. A—Basic parallel arrangement of series diode-resistor circuits. Batteries represent voltage sources for biasing diodes. B—Dynamic input resistance of the network in A. C—Input-output characteristic is monotonic function.

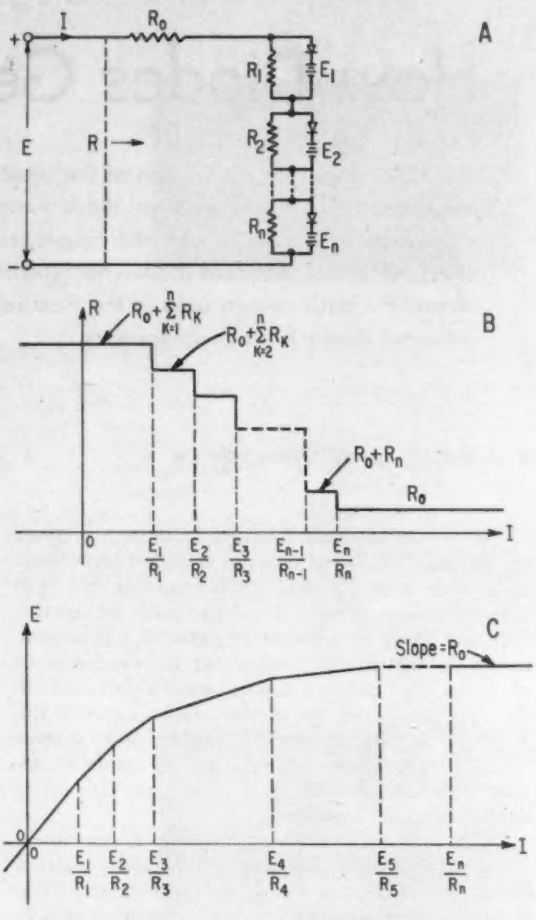


FIG. 2. A—Series connection of parallel diode-resistor networks in another useful circuit. B—Dynamic input resistance of circuit in A. C—Input-output transfer characteristic.

can be generated using operational amplifiers as the difference of two monotonic functions. The amplitude of the function generated can be controlled by potentiometers or a variable feedback resistance. A function may be also translated along the ordinate in either direction, by adding an appropriate constant voltage to the function in the summing amplifier. Translation along the abscissa can be done by adding a constant voltage to the input variable.

Besides their summing and inverting features, operational amplifiers are very insensitve to internal gain changes, and have very low output impedances —both features due to the very high internal gain and heavy negative feedback used.

The summing point, or grid, of a summing amplifier is a virtual ground. Thus, the load resistance of a diode function generator network may be either an input or a feedback resistor for an operational amplifier. Most designs use the input path rather than the feedback path.

The shunt limiter and feedback limiter circuits of Figure 3 are typical and are used for simulating saturation or limiting characteristics, or for limiting amplifier inputs to prevent overload.

Dead-space or backlash characteristics can be simulated by the networks illustrated in Figure 4.

Universal DFG's

Diode function generators designed to generate any arbitrary function are called universal diode function generators. The only limitations imposed on the function are that it be continuous (i.e., that it have no amplitude discontinuities, although slope discontinuities may exist), and that it be single-valued.

Since it should be adaptable to a wide variety of

functions and also be capable of feeding various load resistances, a universal diode function generator must be used with an operational amplifier. The slopes of each linear segment must be variable in both magnitude and sign. Breakpoint bias voltages must also be variable. The circuit of Figure 5 meets these requirements in principle (practical designs for the bias supplies will be shown later), but it is only one of many possible configurations. Figure 6A shows the contribution to the output of any one of the positive channels, and Figure 6B shows the contribution of any one of the negative channels. Note that both positive and negative slopes are available from either channel. The individual contributions of each channel are summed by the amplifiers, so that the overall transfer characteristic, E_o vs. E_i, is a superposition of the contributions of all the channels.

Practical biasing arrangements

The networks presented so far have shown bias sources as series batteries, which are not considered practical. Some practical biasing circuits will now be discussed.

When one end of the bias source can be grounded, such as in the network of Figure 1A, a voltage divider fed by a reference voltage is a practical arrangement. This is illustrated in Figure 7. The reference voltage, E_R, may be positive or negative.

When both ends of the bias source must be isolated from ground, several methods are available. One of these methods, illustrated by Figure 8, uses fixed batteries with voltage dividers, which is not very practical since a separate battery is required for each diode, and the bias voltages will drift as the batteries age. Floating regulated power supplies in place of the batteries would eliminate the aging effects, but

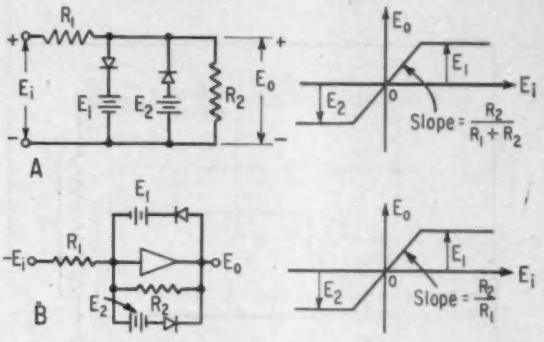


FIG. 3. A—Shunt limiter circuit and transfer function. B—Feedback limiter circuit and transfer function.

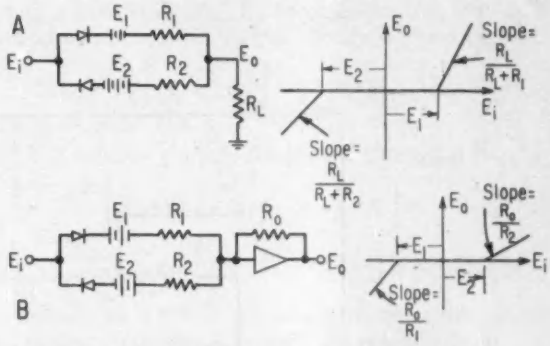


FIG. 4. A—Dead-zone or backlash circuit and transfer functions. B—Dead-zone circuit using operational amplifier.

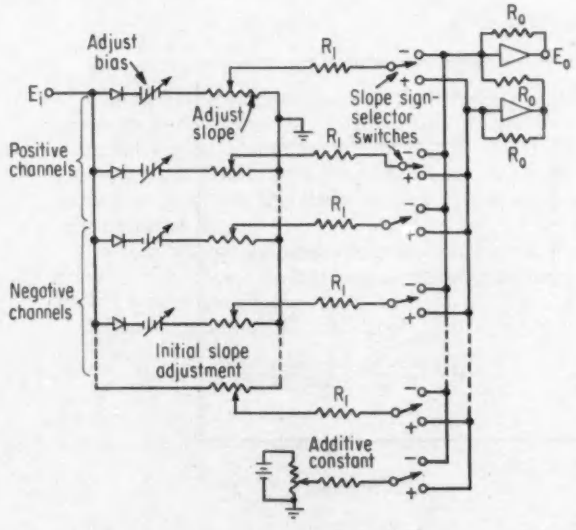
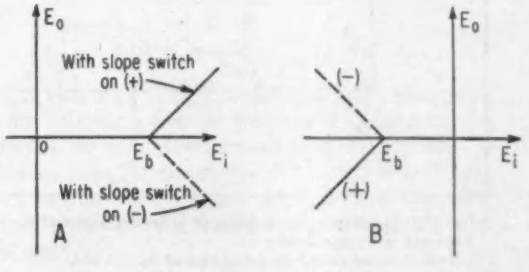


FIG. 5. Circuit for universal diode function generator that can produce monotonic function of input in any quadrant. Practical bias sources are neglected.

FIG. 6. A—Output of one of the positive channels in circuit of Figure 5. Slope may be either positive or negative. B—Negative channel may also have slope of either sign.



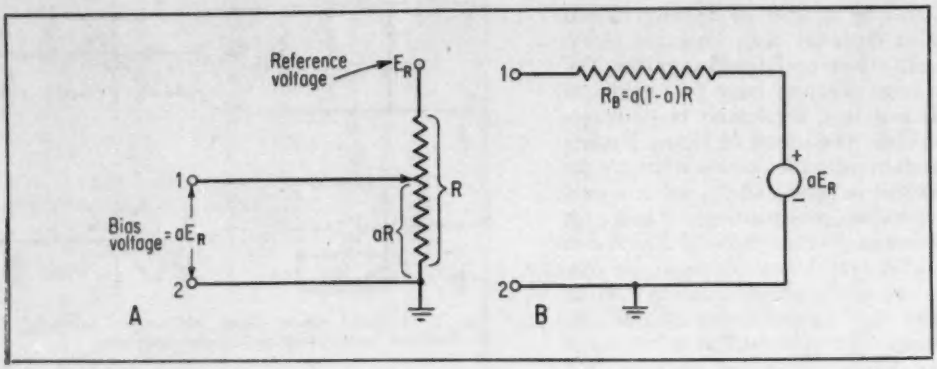


FIG. 7. A—If bias supply may be grounded, simple voltage divider may be used from a reference source. B—Thevenin equivalent circuit for A.

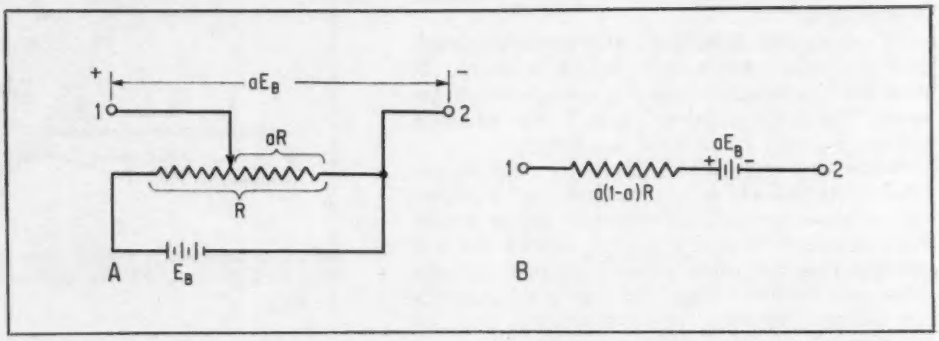


FIG 8. A—Divider across a battery or a floated supply can be used if bias source may not be grounded. B—Equivalent circuit for A.

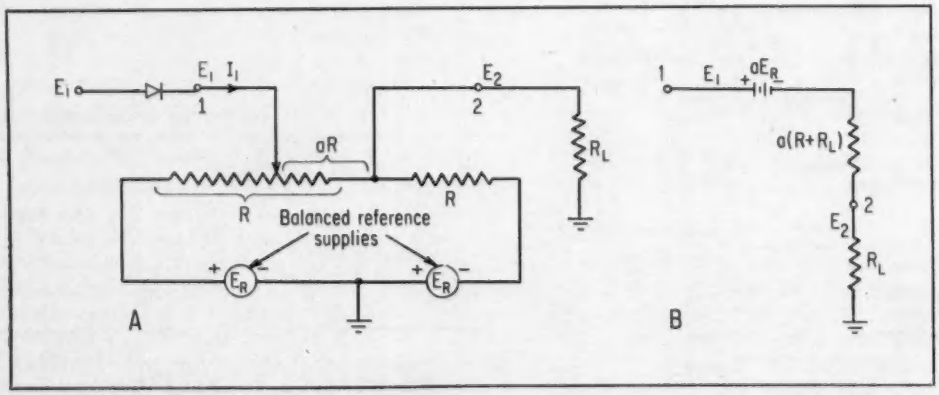


FIG. 9. A—Biasing from balanced reference supplies through a voltage divider.
B—Equivalent circuit for calculation of E_2, see text.

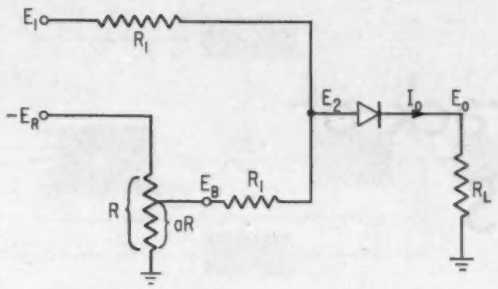


FIG. 10. Biasing through a voltage divider and summing network.

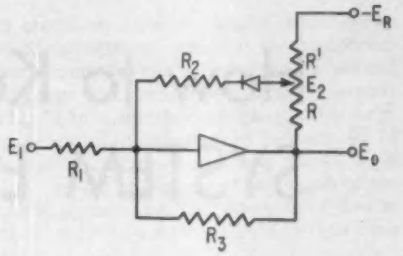


FIG. 11. Bias circuit for diode used in feedback loop of operational amplifier.

is still not considered to be a really practical answer.

A better arrangement is shown with its equivalent circuit in Figure 9A. This circuit uses a voltage divider across balanced reference supplies. A diode to be biased is normally connected to terminal 1, as shown in the diagram. Load resistance R_L, which is usually required by the rest of the circuitry, may be connected either directly to ground, or to a virtual ground such as the grid of an operational amplifier. Before the diode conducts, that is, for $I_1 = 0$, the bias voltage appearing between point 1 and ground (or point 2, since for $I_1 = 0$, $E_2 = 0$) is aE_R. After conduction, that is, for $I_1 \neq 0$, E_2 is no longer zero, and assuming an ideal diode, is given by:

$$E_2 = (E_i - aE_R)\left[\frac{R_L}{R_L + a\,(R + R_L)}\right]$$

for $E_i > aE_R$

After conduction, therefore, the circuit may be represented by the equivalent circuit of Figure 9B. This equivalent circuit gives E_2 exactly, but does not give the total current I_1 drawn from the E_1 source through the diode. This current is calculated as follows:

$$I_1 = 0, \text{ for } E_i < aE_R$$

$$I_1 = \left\{\frac{R + 2R_L}{(1 - a)\,R\,[R_L + a\,(R + R_L)]}\right\}(E_i - aE_R),$$

for $E_i > aE_R$

Note that bias voltages equal to the reference voltage magnitude cannot be obtained by this method, since then $a = 1$, and for $E_i > E_R$, I_1 would be infinite. This is still not a major drawback, however, since E_R represents the maximum excursion of the magnitude of E_i.

Another biasing method, illustrated in Figure 10, consists of a voltage divider and a summing network placed before the diode.

Before conduction, $I_0 = 0$, and

$$E_2 = \frac{R_1\,(E_1 - aE_R) + [a\,(1 - a)\,R]\,E_1}{2\,R_1 + a\,(1 - a)\,R},$$

for $I_0 = 0$ or $E_1 < |E_B|$

For $R << R_1$, this expression reduces to:

$$E_2 = \frac{E_1 - aE_R}{2}, \text{ for } E_1 < aE_R$$

Therefore, for E_1 less than the magnitude of the bias voltage, E_B, there is no conduction and $E_0 = 0$. For E_1 greater than $|E_B|$, E_2 becomes positive, conduction occurs, and the output voltage is given by:

$$E_0 = \left[\frac{R_L}{R_1 + 2R_L}\right](E_1 - aE_R),$$

for $E_1 > aE_R$ and $R \ll R_1$.

If R is not low enough, the general expression is:

$$E_0 = \frac{\left[E_1 - aE_R + a\,(1 - a)\,\frac{R}{R_1}\,E_1\right]R_L}{(R_1 + R_L)\left[1 + a\,(1 - a)\,\frac{R}{R_1}\right] + R_L}$$

Figure 11 is a circuit for biasing diodes used in the feedback circuits of operational amplifiers. In this circuit, before conduction occurs,

$$E_0 = -\left(\frac{R_0}{R_1}\right)E_1$$

and

$$E_2 = \frac{R'}{R + R'}\left[E_0 - \left(\frac{R}{R'}\right)\right]$$

Since the diodes will not conduct until $E_2 > 0$, no conduction will occur for $E_0 < (R/R')\,E_R$, which corresponds to

$$-E_1 < \left(\frac{R_1}{R_0}\right)\left(\frac{R}{R'}\right)E_R$$

For output voltage greater than $E_0 = (R/R')\,E_R$, the diode conducts and the output variation is given by:

$$E_0 = -\frac{R_0\,R_2'}{R_1\,(R_0 + R_2')}\left[E_1 - \left(\frac{R_1\,R}{R_2'\,R'}\right)E_R\right]$$

where

$$R_2' = R_2 + R + \frac{RR_2}{R'}$$

The effects of diode nonidealities and a discussion of the relative merits of thermionic diodes vs. germanium or silicon semiconductor diodes will be included in a later article. This article will also describe the basic circuits used in the more important commercially available universal diode function generators.

How to Keep Track of SYSTEM ERRORS

THE GIST: Attaining overall system accuracy is one phase of systems engineering too often pursued in haphazard fashion. In this article, Author Marcus advocates an orderly and logical procedure for keeping an up-to-date account of permissible and actual errors anywhere in the system. With integrated system error analysis, the author contends, the system designer can make realistic initial assignment of subsystem and component tolerances, and modify them from time to time as indicated by technical and economic considerations.

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An important criterion of a successful control system is its operating accuracy. Certain difficulties, however, arising during the development of a complex control system, may hamper meeting the accuracy specifications. Among these are difficulties in predicting accuracy as a function of the system's design; difficulties in achieving sufficient accuracy in a fabricated system; and difficulties in assessing the overall accuracy once the system has been built.

Throughout the stages of planning, designing, testing, and producing the control system, there is a continuing need to know many things about accuracy. Errors occur at every stage, and an orderly accounting should be made of the origin and magnitude of these errors and their effect on overall system accuracy. This orderly procedure is called Integrated System Error Analysis, or ISEA.

An integrated error analysis for a complex system requires human accounting of tolerances and errors; on very large systems, there must be an accountant for each subsystem. The duties of the error accountant would be to maintain a record of the present values of system errors as well as errors internal to the system, all based on the best available information. For large systems, one person should be assigned as integrator of the error analysis. His duties would be chiefly to assist subsystem error accountants in assigning tolerances to components and in determining subsystem errors. More specifically, he would:

- make initial assignment of tolerances to each subsystem, usually on a statistical basis
- specify test equipment accuracy requirements
- determine overall system accuracy from the up-to-date accuracies furnished by the error accountants
- recommend limited design changes, or even changes in large portions of the system when necessary, to keep the actual system error within the value allowed by specification
- revise tolerances initially assigned, as dictated by the overall technical and economic requirements

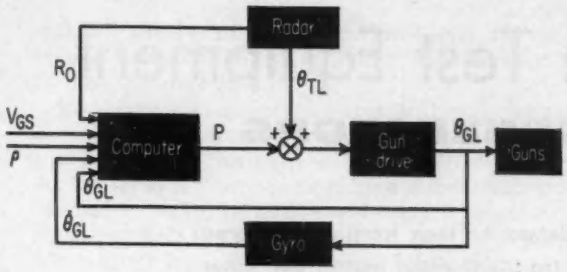
To make sure that the error analysis is kept on a sound basis, the computed values for subsystem errors should be compared, whenever possible, with measured values—that is, "feedback" should be used between test and design. The results of such comparisons should then be a basis for revision, when indicated, of the method of classifying and describing individual errors and the method of combining errors to compute system, or output, errors.

Carrying out an ISEA program will require further development of methods for: the classification and mathematical description of errors; the determination of subsystem and component tolerances and input accuracy requirements, all as a function of the overall system accuracy requirement; and the calculation of the output error of any device subject to a number of input and performance errors.

Integrated system error analysis gives the organization responsible for the system strict control over accuracy by assuring that both the overall design, and all systems and subsystems actually produced, meet accuracy specifications. In addition, ISEA provides data for: the assignment of tolerances required in such manufacturing operations as fabrication, processing, and assembly; operations analysis studies; preparation of proposals for systems of a related nature; and reporting to the customer. The customer may be an outside organization or an operating division within the same company.

Assignment of tolerances

One prime use of integrated system error analysis is making initial assignment of tolerances to subsystems. Proper apportionment of the overall system error among the subsystems requires a balance between technical and economic demands. Decreasing the allowable tolerance



R_O = range to target
V_{GS} = gun station speed
ρ = air density
P = prediction angle
θ_{TL} = tracking line angle
θ_{GL} = gun line angle
$\dot{\theta}_{GL}$ = rate of change of gun line angle

Block diagram or typical gun-aiming system aids in assigning initial tolerances to subsystem whose input and performance errors contribute to the overall system error.

of a simple, $1,000 subsystem may increase its cost by, say, $200; but adding this increment of tolerance to a complex $10,000 subsystem of the same system may reduce its cost by $500. Net savings would be $300.

As an example of tolerance assignment, consider the airborne flexible gunnery fire control system shown in block diagram form in the figure. Such a system must track a target, compute where its guns should be aimed, and properly direct the guns. Since the system will obviously do each of these tasks imperfectly, it will have a tracking error, a computation error, and a direction error. In addition, there will be a harmonization error because of inaccurate placement of the tracking member, guns, and aircraft with respect to each other.

Suppose a fire control system must have an overall gun-aiming error never greater than plus or minus 5 milliradians. One approach to meeting this specification is to assume that each of the subsystem errors contributing to the total error is at its maximum allowable value, and that all subsystem errors act in the same direction. That is, for instance, each error is at the plus side of its maximum tolerance. Thus, to assure that the system would never exceed 5 mils error, the following tolerances might be assigned, on a straight arithmetic basis, for the individual sources of error:

Tracking	1.50 mils
Computation	1.25 mils
Direction	1.25 mils
Harmonization	1.00 mils

However, because the probability of errors of randomly selected subsystems all being in the same direction is relatively small, this method of assigning tolerances is highly restrictive; meeting these tolerances puts an extra burden on design and testing and adds considerable cost to the system.

A more customary approach is to take cognizance and advantage of the statistical spread in errors of fabricated components and subsystems, and to use the statistical nature of the independent errors in assigning tolerances.

The statistical spread of error is usually described in terms of standard deviation σ, which is the root-mean-square deviation from the mean error. For a normal distribution of errors the "maximum" error is usually considered to be 3σ in magnitude. Although the maximum value in a normal distribution is infinite, 99.74 percent of all values lie between plus and minus 3σ of the mean. Thus the use of 3σ as the maximum allowable error means in essence that 99.74 percent of devices (parts, subsystems, etc.) have an error smaller than their assigned tolerance.

Mathematically, the relationship between the standard deviations of the individual errors and the standard deviation of the total error is:

$$(\sigma_\Sigma)^2 = \Sigma\,(\partial E_\Sigma/\partial E_i)^2\,(\sigma_i)^2 \qquad (1)$$

Similarly, the individual and total errors are related by:

$$(E_{\Sigma_{max}})^2 = \Sigma\,(\partial E_\Sigma/\partial E_i)^2\,(E_{i_{max}})^2 \qquad (2)$$

Since the partial derivatives of the total error with respect to each of the individual errors is unity, Equation 2 becomes, for the present example:

$$5^2 = \Sigma\,(E_{i_{max}})^2 \qquad (3)$$

According to Equation 3, the squares of the individual errors may total 25 mils squared, yielding a system error of 5 mils. The following individual tolerances may be assigned:

Computation	3.00 mils
Tracking	3.00 mils
Direction	2.00 mils
Harmonization	1.75 mils

Compared with the arithmetic method, the statistical method of assigning tolerances has significantly widened the allowable error limits, in this case roughly by a factor of two, yet with 99.74 percent assurance that a combination of subsystems having these errors will yield a system having an error within its allowable tolerance.

The computation error is caused by inaccurate inputs to the computer, by approximations made to the mathematical relations which determine where the guns should be aimed, and by component errors. Such errors are called, respectively, input, calibration, and instrumentation errors. Because they are independent, their values are considered to combine squarewise. This permits the tolerances on the errors comprising the 3-mil computation error to be assigned as follows:

Input	1.0 mils
Calibration	2.0 mils
Instrumentation	2.0 mils

Carrying the assignment of the computation tolerance a little further, note that the figure shows that the computer inputs determining the prediction angle P are: the velocity of the gun station, V_{GS}, the relative air density, ρ, the range of the target, R_o, the angular position of the gun line, θ_{GL}, and the angular velocity of the gun line, $\dot{\theta}_{GL}$. Adopting Equation 2, Equation 4:

$$\left[E_{input}\,(P)\right]^2 = \left[\frac{\partial P}{\partial V_{GS}}\,E\,(V_{GS})\right]^2 + \left[\frac{\partial P}{\partial \rho}\,E^2(\rho)\right] + \left[\frac{\partial P}{\partial R_o}\,E\,(R_o)\right]^2 + \left[\frac{\partial P}{\partial \theta_{GL}}\,E[(\theta_{GL})\right]^2 + \left[\frac{\partial P}{\partial \dot{\theta}_{GL}}\,E\,(\dot{\theta}_{GL})\right]^2 \qquad (4)$$

divides the 1-mil input tolerance among the computer inputs to assign allowable errors to each input.

Control System Test Equipment

PART I: SIGNAL GENERATORS

THE GIST: Control systems are tested to determine their transient response (to a step input), their frequency response (to a sinusoidal input), and other specialized characteristics. The author explained how to perform these tests and how to interpret test results in an earlier article, "Testing Servomechanisms" (CtE, September 1956, p. 174). The present article is the first of three covering the specialized equipment for performing these tests.

This specialized equipment, whether commercially available or homegrown, divides into three classes: 1) devices that only generate a test signal, 2) systems that generate a test signal and also provide a means for evaluating control system response, and 3) devices that only evaluate control system response. This article describes seven commercially-available signal generators that fall in the first class; the succeeding articles will cover equipment in classes two and three.

ABRAHAM M. FUCHS, Boonshaft & Fuchs, Inc.

The seven test generators described in this article consist of five electronic oscillators and two mechanical generators. Their output frequency ranges from a low of 0.0005 cps (item 1) to a high of 100,000 cps (item 4). Very often these test signal generators and other standard laboratory equipment are all that is needed for complete frequency response and transient response tests. This is particularly true when dc signals are required as input test functions, and when dc signals are available as the control system output. Table I lists selection factors that should be considered when choosing a low-frequency electronic oscillator for a particular control system test.

Transient response measurement

Figure 1 shows the method for obtaining step response data. The input step can be generated repetitively by test items 1, 2, 3, 4 or 5, or it can be generated on a one-shot basis by a switch or relay, or by test item 1. (Table II on page 118 summarizes the important characteristics of the signal generators.) The output single-shot response can be observed on an oscilloscope whose sweep is triggered by the test input (note that test item 1 provides a trigger pulse that anticipates the step output and permits the entire transient response to be observed). Steps at a fixed repetition frequency permit continuous observation of the output, though some care must be taken to make sure that the transient response is complete before the step input is altered. In many instances an oscillogram or plotting-table recording of the response is desirable; for slow control, for instance, this technique allows a more careful examination of the actual response. In both continuous and single-shot cases it is desirable to record the time that the step is applied so that system initial response can also be evaluated.

Rise time, natural frequency, damping ratio, subsidence ratio, settling time, and overall system transfer function are the major parameters normally determined by step response tests. But transient response testing as a whole often includes obtaining the system velocity constant as well. The latter can be most readily determined by using ramp test inputs. Test items 1 and 3 can be used for generating the ramp input (constant velocity input). Any of the step-input generators (a switch, or test items 1 to 5) can be used if it is followed by an integrator that generates a ramp output for a step input. The ramp response can be observed on an oscilloscope or oscillographic recording device.

Constant acceleration inputs can be generated by using a special diode shaping network with test item 1, or by an integrator operating on the ramp output of test items 1 or 3.

When evaluating velocity or acceleration constants, the error level should be recorded as well as the output. The reason: if the error is small compared to the output level, it is difficult to determine unless it is recorded directly. In addition, it is desirable to record the error for both positive and negative ramp and acceleration inputs; this

makes it possible to separate the error level due to input dynamics from the error level due to offsets in the error amplifier.

Frequently the minimum input that will cause output motion must be determined. Step inputs can be used for this purpose (items 1 through 5). As the input is increased from zero a level will be reached at which the output will begin to respond. But decreasing the input will often reveal a much lower input level at which output response ceases, unless a very low-rate cyclic step is used. The minimum input response level is also a function of other operating conditions, making it a difficult quantity to evaluate exactly.

Frequency response measurement

Frequency response can be measured using only test-signal generators and general-purpose recording equipment, especially for systems with dc output signals. Items 1 through 7 provide sine-wave signals over extended frequency ranges (see Table II). These signals are applied as the test input, and control system output is recorded on an oscillograph for frequencies below 0.5 cps. The input test signal is recorded on an adjacent channel. Phase can then be read by comparing the zero crossovers of the two signals. At frequencies above 0.5 cps the output can be displayed on an oscilloscope, or, by using an electronic switch, both input and output can be displayed simultaneously and phase read directly.

Amplitude response vs. frequency is generally read directly on the recorder or oscillograph that is being used to study the output. These devices usually include calibrated attenuators that facilitate the amplitude measurement.

When the dc output signal is highly nonlinear (for example, when testing at low amplitudes with backlash present), Fourier analysis of the output is necessary to obtain the fundamental component. This is tedious, but it is the only way unless a device

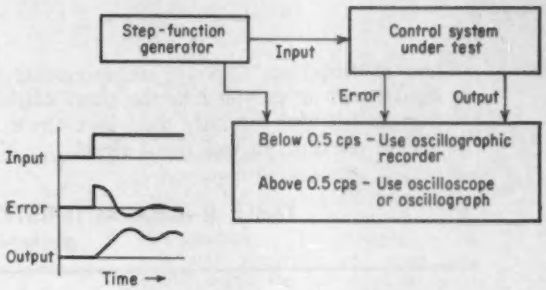
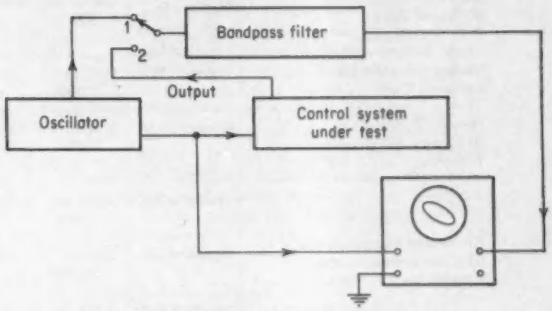


FIG. 1. Test setup for obtaining step response.



Position 1 - Measure phase shift through bandpass filter alone.

Position 2 - Measure phase shift through control system and bandpass filter.

Phase shift of control system alone = measurement in position 2 minus measurement in position 1.

FIG. 2. Use of bandpass filter for noise reduction in frequency response testing.

such as the Solartron Transfer Function Analyzer (covered in next article) or the techniques described in Ref. 1 are used.

When the dc output signal is noisy a bandpass filter can be used to improve the frequency response readings. The filter can be constructed on an analog computer, or purchased (Model 330A Krohn-Hite low-frequency bandpass filter). The latter produces an output/input of

$$\frac{\omega^4\tau_1^4}{(1+2j\lambda\omega\tau_1-\omega^2\tau_1^2)^2(1+2j\lambda\omega\tau_2-\omega^2\tau_2^2)^2}$$

so that it provides 24 db/octave attenuation outside of the bandpass region. It is adjustable on both break-points from 0.02 to 20,000 cps. (Price: $475.)

Since a low-frequency bandpass filter exhibits very high phase shift at only small deviations from its tuned value, it is essential to eliminate this error source from the test results. This is accomplished as shown in Figure 2.

Noise attenuation can also be obtained by using the Solartron Transfer Function Analyzer or the techniques of Ref. 1.

When the output is an ac signal, phase is measured by means of Lissajous patterns. Amplitude is measured as it is in the dc case, although some care must be taken to prevent quadrature signals from interfering with accuracy. More detail on the prob-

TABLE I

ELECTRONIC OSCILLATOR SELECTION FACTORS

FREQUENCY RANGE—Oscillator test frequencies should cover the range from a tenth to 10 times the natural frequency of the control system under test.

AMPLITUDE RANGE—The output amplitude should be sufficient to drive the control system to a large percentage of full scale, and at the same time it should be easy to attenuate the signal so that very low levels can be obtained for high-frequency tests.

WAVEFORM—Some thought must be given to the effect of straight-line approximations to a sine wave on the appearance of the error signal, and to the ability of the control system to counteract the discontinuities in the input signal. Harmonic distortion may also be significant in some instances.

DC OFFSET—In the test of integration-type control systems, dc offset of the test signal is very troublesome.

MISCELLANEOUS—Cost, availability of square wave and ramp outputs for transient testing, switching time for change in frequency, convenience, and reliability.

lem of frequency response measurements with ac signals will be provided in the third article, covering devices that are only used to evaluate control system response to test input signals.

REFERENCE

1. *THE APPLICATION OF AN ANALOG COMPUTER TO THE MEASUREMENT OF PROCESS DYNAMICS*, P. E. A. Cowley, ASME paper No. 56-IRD-20, 1956.

TABLE II—CHARACTERISTICS OF LOW-FREQUENCY OSCILLATORS

ELECTRONIC SIGNAL GENERATORS

Manufacturer	Designation	Freq. range, cps	Output level, volts	Distortion, less than	Cost, $	Remarks
British Industries Corp. 80 Shore Road Port Washington, N. Y.	LF-51	0.0005 to 500	0 to 150	1 percent	1,950	Synchronizing pulse for transient test; diode shaping of triangular waveshape; almost unlimited variety of waveshapes
Donner Scientific Co. Concord, Calif.	Model 1500	0.01 to 1,000	0 to 10	1 percent	365	Simultaneous square wave; conventional oscillator circuit
Hewlett-Packard Co. 275 Page Mill Road Palo Alto, Calif.	Model 202A	0.01 to 1,200	0 to 30	1 percent	465	Diode shaping of triangular waveshape to sinusoidal; synchronizing pulse; square and triangular waveshapes available
Krohn-Hite Instrument Co. 580 Massachusetts Ave. Cambridge 39, Mass.	Model 400A	0.009 to 1,100	0 to 30	1 percent	375	
	Model 410A	0.02 to 20,000	0 to 5	0.1 percent	1,050	Special attention to rapid response to frequency change; low distortion
	Model 440A	0.001 to 100,000	0 to 30	0.1 percent	550	
Solartron, Inc. 530–532 Cooper St. Camden, N. J.	O. S. 103A	0.01 to 1,110	0 to 10	2 percent	2,750	Four phases (0, 90, 180, and 270 deg); unconventional circuit

MECHANICAL SIGNAL GENERATORS

Manufacturer	Designation	Freq. range, cps	Output amplitude	Maximum load or capacity	Cost, $	Remarks
Librascope, Inc. 808 Western Ave. Glendale, Calif.	Sine-wave generator	0.02 to 20	0 to 1 in. (translational)	5 lb	4,500	Output can drive bellows to produce pneumatic signals; synchronized electrical signals available
Boston Div. Minneapolis-Honeywell Reg. Co. 40 Life St., Boston 35, Mass.	Type BA-101 frequency response analyzer	1 to 100	0 to ±3 deg (rotational)	12 lb-in.^{2} (inertial)		Primarily for frequency response test of inertial components; auxiliary instruments improve test accuracy

1. SERVOMEX TYPE LF-51

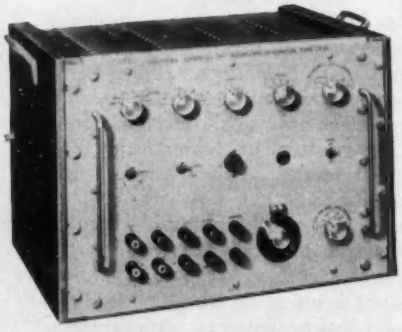


FIG. 3. Plug-in construction simplifies maintenance and makes modification of standard waveshapes easy.

The Servomex LF-51 low-frequency waveform generator, Figure 3, generates a wide variety of test signals over a broad frequency range. Sustained low-frequency oscillations are developed by an integrating amplifier that converts steps of input voltage into ramps of output voltage. The step input voltage is obtained from a trigger circuit that is, in turn, switched by integrator output. This type of oscillator circuit is discussed in greater detail under item 3. Note that there is no switching transient when going from one test frequency to another.

Diode shaping of the triangular wave out of the integrator gives unusual flexibility in the choice of output waveshape. This flexibility is augmented by having the integrating rate independently adjustable to different positive- and negative-going values. Diode shaping limits total sine-wave output distortion to less than 1 percent, and integrator accuracy is such that the ramp output has a slope change of less than 1 percent over its entire range. Output characteristics for sustained oscillations are as follows: frequency range—0.0005 to 500 cps; amplitude—150 volts, peak to peak; source impedance—90 to 1,500 ohms (into 5 ma load circuit); and continuous output waveforms—square, sine, triangle, sawtooth, pulse.

All of these outputs are available in single as well as repetitive form. Figure 4 shows all of the standard output forms. The single waveshapes include step, ramp, sine (90 deg), as well as triangle, sawtooth, sine (180 deg), square, etc. In addition, other waveshapes (for example, sine-squared or Gaussian pulses) can be obtained by using a special plug-

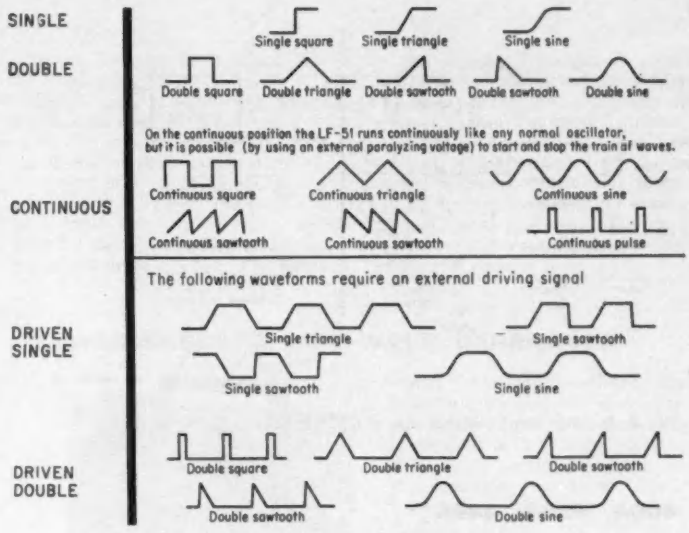


FIG. 4. Standard waveshapes available from LF-51.

in diode waveshaping network. The output is normally balanced about zero, but it can be easily changed to balance at any desired dc level.

An output synchronizing pulse is also provided for studying the transient response of a control system driven by this oscillator. This pulse has a 10-volt peak amplitude, and starts sufficiently before the test signal to be of use in triggering an oscilloscope sweep. Thus the complete transient response to a step can be displayed on a scope.

Finally, by driving the LF-51 from a square-wave source, the nonrepetitive outputs are available at any desired spacing, as shown at the bottom of Figure 4.

This oscillator provides the greatest variety of test signals of any piece of commercially-available low-frequency test-signal generating equipment. When modification of the shaping network is included, there is almost no limit to the waveshape that can be generated.

2. DONNER MODEL 1500

FIG. 5. Note that square wave is available at a separate output jack.

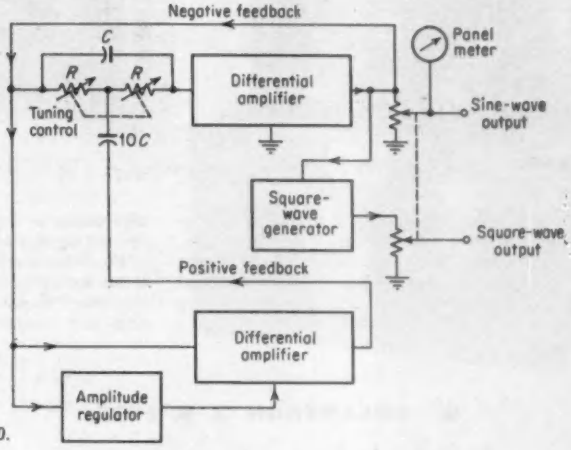


FIG. 6. Donner Model 1500.

The Donner low-frequency function generator, Figure 5, has the following features: 1) Output is a true sine-wave oscillation with low distortion, making possible output differentiation with a minimum noise level; this is important in some servomechanism test procedures, for the break-points in the straight-line approximations to a sine wave may cause hard-to-explain errors in control system response. 2) Amplitude variation is less than 1 db. 3) Total frequency drift is less than 1 percent.

As shown in Figure 6, the output is generated by a conventional oscillator circuit. Oscillation frequency is determined by a shunt-capacitor type of bridged-T null network. The combined action of a negative and a positive feedback loop provides frequency and amplitude stability. The square-wave output is generated by a Schmidt circuit, triggered by the sine wave output. The output has the following characteristics: frequency range 0.01 to 1,000 cps; level—0 to 10 volts rms; distortion—less than 1 percent total harmonic; impedance—1,000 ohms for sine wave, 10,000 ohms for square wave; and square wave rise time—less than 5 microsec.

3. HEWLETT-PACKARD MODEL 202A

The HP low-frequency function generator, Figure 7, operates as shown in Figure 8. The bi-stable circuit has two parts: a flip-flop, with two stable states, and a multiar that generates a pulse when the output from the linear integrator exceeds a switching reference level. The pulse from the multiar switches the flip-flop from one stable state to the other, thereby changing the sign of the input to the integrator. The integrator thus generates a ramp of positive slope from one output state of the flip-flop and a ramp of negative slope from the other. This action results in a continuous relaxation oscillation. A

FIG. 7. Hewlett-Packard function generator.

diode shaping network modifies the triangular output to give a sine-wave output signal.

Output signal characteristics are as follows: frequency range—0.01 to 1,200 cps; output—30 volts peak to peak across a 4,000-ohm load impedance, 40-ohm source impedance balanced or single-ended; distortion—less than 1 percent rms for 0.01 to 1,000 cps, less than 2 percent rms for 100 to 1,200 cps; and output waveforms—sinusoidal, square, and triangular. In addition, the function generator provides a 5-volt peak (negative) pulse of less than 5 microsec duration for synchronizing purposes. This pulse occurs at the crest of the sine-wave output.

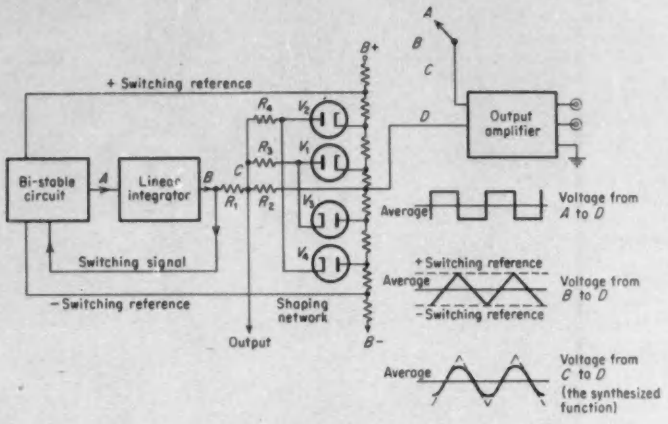


FIG. 8. Bi-stable circuit switches sign of input to linear integrator.

4. KROHN-HITE MODELS 400A, 410A, 440A

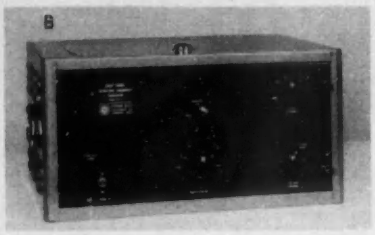


FIG. 9. Two Krohn-Hite ultra-low frequency oscillators; A is Model 400A and B is Model 410A.

Figure 9 shows two models of Krohn-Hite's ultra-low-frequency oscillators. These units use a modified RC-bridge type of circuit with stable resistors and capacitors as the frequency determining elements. Distortion is reduced by a high degree of degeneration at all except the test-signal frequency.

The characteristics of these instruments are as follows: For Model 400A: frequency range—0.009 to 1,100 cps; sinusoidal output—30 volts peak to peak; distortion—less than 1 percent; output impedance—1,000 ohms for sine wave, 10,000 ohms for square wave. For Model 410A: frequency range—0.02 to 20,000 cps; sinusoidal output—5 volts peak to peak; distortion—less than 0.1 percent; output impedance—500 ohms for sine wave, 5,000 ohms for square wave. For Model 440A: frequency range—0.001 to 100,000 cps; sinusoidal output—300 volts peak to peak; distortion—less than 0.1 percent; output impedance—1,000 ohms for sine wave, 1,500 ohms for square wave. Note the very low distortion characteristics of the 410A and 440A oscillators.

The recovery time to a change in frequency setting is less than three cycles of dial frequency. Special design features reduce the distortion due to AVC.

5. SOLARTRON O. S. 103A

The O. S. 103A, Figure 10, is usually considered part of the Solartron Transfer Function Analyzer (to be discussed in the next article, covering complete servo analysis systems); however, it has characteristics and capabilities that make it a useful item by itself as well as with the complete analyzer.

To achieve stable operation down to very low frequencies, this unit uses the unique oscillator circuit shown in Figure 11. At the oscillation frequency, one phase-shift network introduces 90 deg of phase lead, the other 90 deg of phase lag. Their combined action gives a plus-one gain around the loop at one frequency—the frequency of oscillation. At all other frequencies the unity gain is not at 0 deg. Thus a stable, selective means of providing the low-frequency test signals is available.

Note that mechanizing the oscillator this way yields four outputs at 0 deg, 90 deg, 180 deg, and 270 deg relative phase. This is necessary for the operation of the

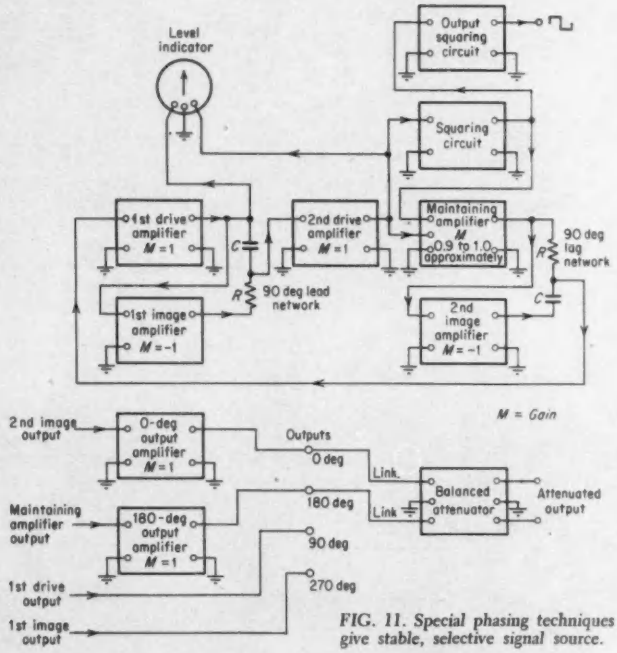


FIG. 11. Special phasing techniques give stable, selective signal source.

Resolved Components Indicator (transfer function analyzer).

The frequency range of the Solartron low-frequency decade oscillator is 0.01 to 1,110 cps. For a sine-wave output the other characteristics are: amplitude—10 volts rms; source impedance—10 ohms for the 0- and 180-deg outputs; will drive 1,000 ohms to 10 volts, 10,000 ohms for the 90- and 270-deg output; intended for reference only; phase accuracy —plus or minus 1 percent of nominal to 1,000 cps; amplitude accuracy—plus or minus 2 percent of 0-deg phase; distortion—less than 2 percent harmonics for each phase; and dc content—less than 1.5 percent of the ac peak to peak. For a square-wave output (available simultaneously) the other characteristics are: amplitude—17 volts peak to peak; source impedance—600 ohms; and rise time—1 percent of periodic time.

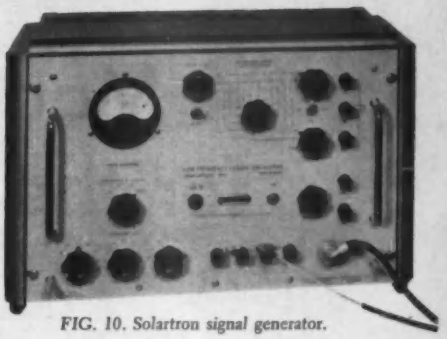


FIG. 10. Solartron signal generator.

6. LIBRASCOPE SINE-WAVE GENERATOR

FIG. 12. Mechanical sine-wave generator.

The Librascope Sine-Wave Generator provides a translational mechanical output, Figure 12. The mechanical motion is achieved by a Graham variable-speed transmission working through one of three optional gear trains. These gear trains, in turn, drive the plunger actuator mechanism which converts the rotary motion to translational motion of the output shaft. The output shaft can be used to drive bellows and produce pneumatic test signals, to act as a variable output load, and to simulate many types of input motions. Synchronized electrical signals are available as 2-deg pulses every 90 deg, and as the output of a sinusoidal potentiometer.

Generator characteristics are as follows: frequency range—0.02 to 20 cps; amplitude—0 to 1 in.; maximum load—5 lb; zero position adjustment—0 to 1 in.; oscillation amplitude adjustment—to 0.01 in.; and oscillation zero-position adjustment—to 0.001 in.

7. MINNEAPOLIS-HONEYWELL TYPE BA-101

Figure 13 shows the control console of the Type BA-101 Frequency Response Analyzer, built by the Boston Div. of Minneapolis-Honeywell. It consists of the console, a mechanical oscillator, and a test table, Figure 14.

This instrument was designed primarily for evaluating the frequency response of rate gyros, angular accelerometers, and similar inertial components. Its output is a mechanical linear sinusoidal oscillation. The drive is a high-power velocity servo that can be controlled to maintain any constant speed from 1 to 100 cps within an accuracy of plus or minus 0.5 percent. Speed control is obtained by comparing a calibrated input voltage with the output of a tachometer coupled to a 1-hp dc servomotor. The error signal is amplified, rectified, and then used to excite the control winding of an amplidyne. In turn, amplidyne output energizes the drive-motor armature. Drive-motor rotation is converted into oscillatory motion by a scotch yoke in which are mounted the instruments under test. One revolution of the drive motor gives one cycle of oscillation at the yoke.

The mechanical sinusoidal oscillator (rotary) has the following capabilities: frequency range—1 to 100 cps within plus or minus 0.5 percent; amplitude—0 to plus or minus 3 deg peak; harmonic content—less than 0.5 percent; and inertial capacity—to 12 lb-in.^{2}.

Other equipment assists in obtaining accurate frequency response data. A microsyn mounted on the oscillating table provides a direct measure of table position vs. time; it prevents phase and amplitude errors from desired table motion to actual table motion. A synchro connected to the table rotates one revolution for each cycle of table oscillation, and feeds a stationary synchro in the control console. By varying the position of the rotor of the stationary synchro (using a calibrated dial on the control console) modulation phase can be accurately set. This phase can be used to measure the relative phase shift between microsyn output (table position) and the output of the test item.

FIG. 13. Control console.

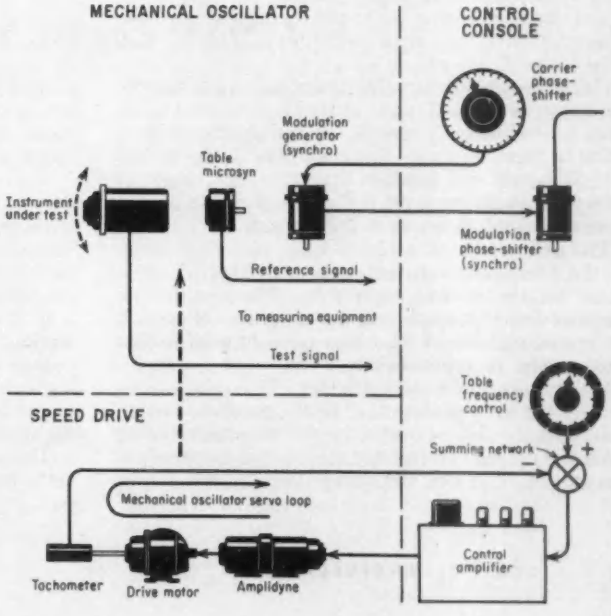


FIG. 14. Three main units of signal generator.

4 Modern Control Systems for the Steel Industry

P. A. TRAVISANO, General Electric Co.

Progress In Control

Two objectives—increased production rates with corresponding improvement in product quality, and reduced operating costs—have prompted a continual upgrading of control equipment designed for the steel industry. The desire for more inclusive control systems has greatly accelerated the demand for new control components and techniques. Figure 1 summarizes the progress that has taken place, illustrating the various types of control systems and the approximate date of introduction to the steel industry.

Earlier manual and magnetic control systems have been superseded by the latest feedback control systems. Simultaneously, the type of components used in these systems has changed. The electromechanical and electronic amplifiers have been replaced by rotating amplifiers. And more recently, magnetic amplifiers and transistors have been introduced to supplement the characteristics of the earlier units.

Today the scope of control systems is expanding. Here are four modern ones that perform additional functions:

Static Control Systems
Data Logging Systems
Program Control Systems
Director Systems

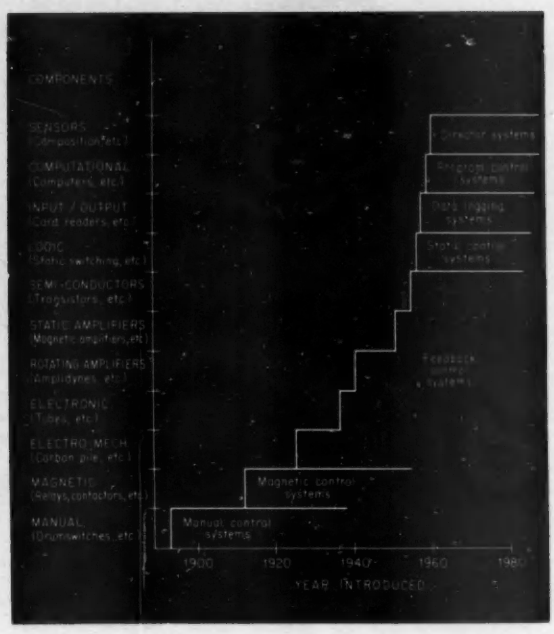


FIG. 1

1. Static Control Systems

Using a multifunction static switching unit, like the one shown in Figure 2, static control systems lend themselves to steel industry control. In one significant application—a new reversing blooming and slabbing mill that ultimately will produce 5 million ingot tons per year—static switching units replace all of the relays previously operated during each mill reversal.

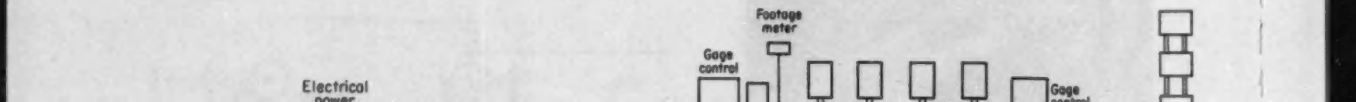
The mill consists of a 12,000-hp dc twin-drive motor for the horizontal work rolls and a 4,000-hp dc drive motor for the vertical edger rolls. The combination magnetic amplifier amplidyne control system (Figure 3) can reverse such drives from base speed forward to base speed reverse in approximately 1 sec.

Major units in the control system: 1) a voltage regulator for the main generator, using the generator exciter, and 2) a motor field regulator for the main motor, using the motor exciter. To regulate acceleration and deceleration at a constant rate, the voltage loop uses the rate of change of generator voltage. Thus, the speed of the drive can be changed either quickly or slowly but always at a linear rate of change of speed—minimizing transient shocks to the drive machinery.

The motor field loop regulates motor field current during steady state conditions and regulates the rate of change of motor field flux during transient conditions. This means more accurate control of motor speed in the weak field range and reduction of the forcing level of the excitation system.

It is anticipated that the static units will eliminate millions of relay operations and save the corresponding costs in maintenance and inspection. One of the unique features of this equipment is a transistor switching unit to provide an isolated output for opening and closing the various regulator field circuits.

The control panel is shown in Figure 4. Experience with static units indicated that panel designs could be



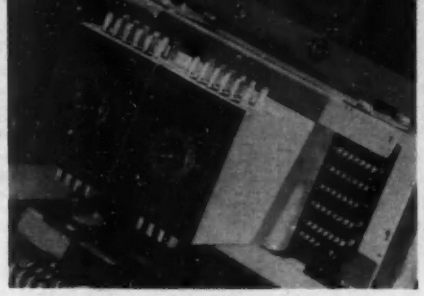


FIG. 2. Multifunction static switching reactors.

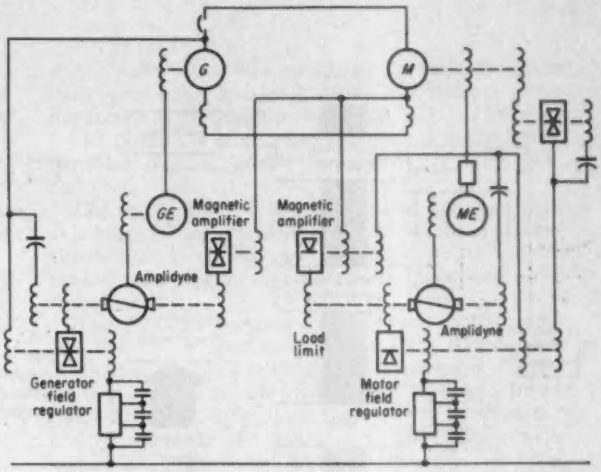


FIG. 3. Combination magnetic amplifier amplidyne control system. Major components: generator (G), generator exciter (GE), main motor (M), motor exciter (ME).

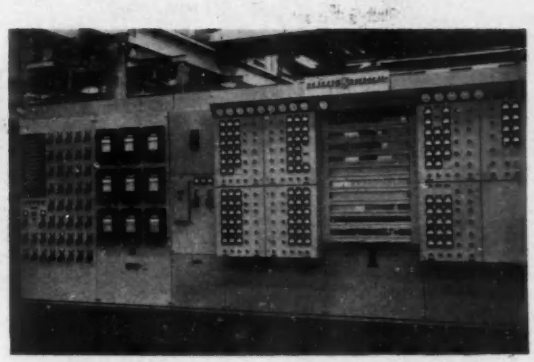


FIG. 4. Control panel. Static switching units are located on the recessed panel in the center of the lineup. The enclosed, slightly protruding panels are functionally subdivided and contain all the regulating circuit components and instrumentation.

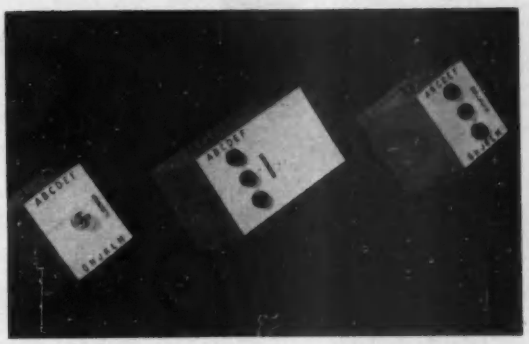


FIG. 5. Compatable relay and amplifier units. At left, an encapsulated relay, with monitor light, for a static switch unit. In the center, a transistorized ac amplifier unit for a hot metal detector. At right, a transistorized dc amplifier unit for program control.

considerably improved if some of the other devices used in conjunction with the basic static switching units were made both electrically and mechanically compatible. Figure 5 shows some of these devices.

Modules can be plugged into the standard static switching bus strip. ... jack-plugs on the front of the units are used for maintenance testing. Like units are interchangeable.

Static switching is not considered to be a "cure all". However, it is extremely useful where frequent or continuous operations are needed, or where complex sequencing or adverse atmosphere conditions exist. Static switching is being used to replace such components as stepping switches, counters and shift registers. All are required for the program control and director systems now being installed in the steel industry.

2. Data Logging Systems

A data logger—currently one is being installed on a tandem cold reduction mill—will collect mill operation data for each coil of steel processed. Reproduced at four remote typewriters located throughout the plant, this data is used to generate punched cards for payroll and warehousing.

The mill, which utilizes a total of 20,000-hp dc main drive motors to reduce the steel to tinplate thickness, is regulated to automatically hold gage while rolling steel at 7,000 fpm. Shown in Figure 6 is a simplified block diagram. The existing control includes two regulating loops—the inside loop acts as a coarse regulator, uses such electrical signals as volts and amps, while the outside loop acts as a vernier and is related directly to strip thickness. An overall computer study was performed so that both loops could be closed simultaneously without producing interactions which could not be stabilized.

Added to the existing control, the data logger produces a punched paper tape for each coil of steel. Its immediate typewritten production report covers: coil identification, mill operator and shift number, starting time, lengths at which the strip transfers from "on" to "off" to "on" gage, mill delay times and reasons, finish time, finish length, and total finished coil weight.

In addition, the system receives preset information on punched cards for each coil to be rolled and transmits this data to the automatic gage control to program the thickness settings for stand No. 1 and stand No. 4.

ingot reaches the "forward-speedup" detector—a detec-

ciated brakes when no error signals exist and the screws

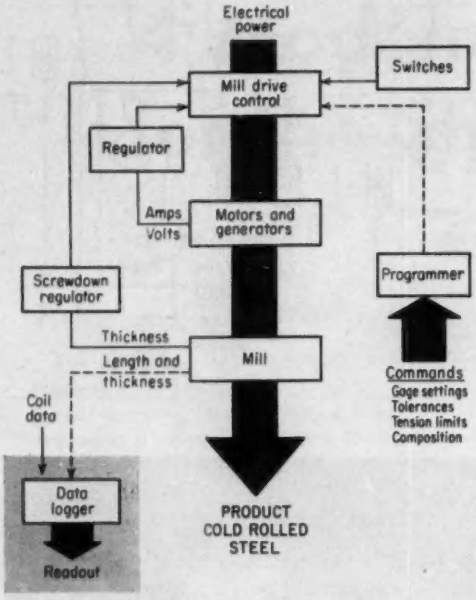


FIG. 6. Block diagram of control.

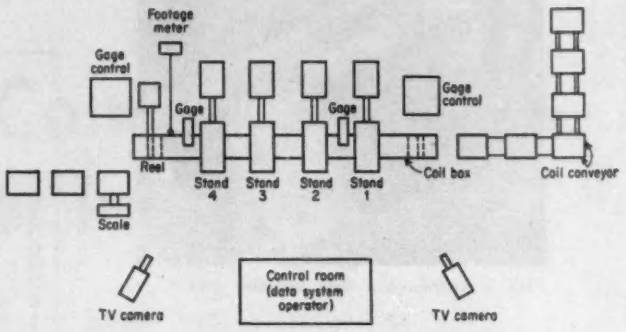


FIG. 7. Layout of data logger system. Steel in large coils received from the coil conveyor is reduced in thickness as it passes through the four stands and is recoiled on the reel. Then it is weighed on the scale, and delivered to the subsequent processing operations. Two closed-circuit TV cameras give the operator a view of both input and exit ends of the mill.

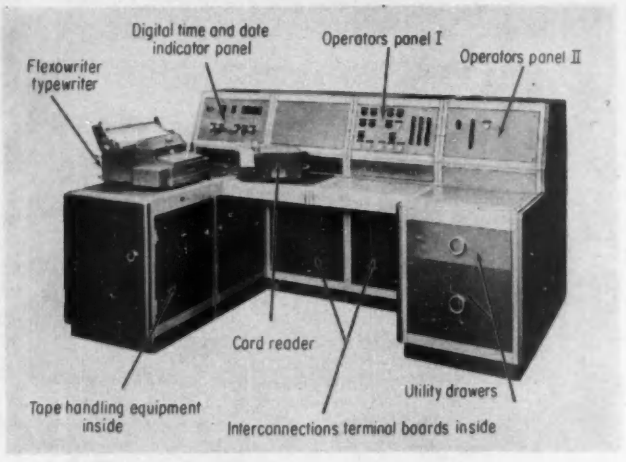


FIG. 8. Operator's console. Digital time and date indicator panels supply the time correspondence for rolling operations. Operator's panel I provides the input units for recording and establishing the reason for mill delay. Operator's panel II contains circuitry to identify the mill operator and shift number.

Compensation is provided for the rolling tolerances, tension limits, and appropriate material composition.

Because of the adverse steel mill atmosphere, an air conditioned control room has been constructed for the data system operator in the mill area (Figure 7). The console for the operator (Figure 8) includes a typewriter, card reader and tape handling equipment, and the necessary control sequencing and distributing devices.

More extensive data logging equipment is being supplied for the automatic inspection of "in-process" steel as it is being plated on the high-speed tinning lines. The continuous steel strip is automatically classified as being either prime, second, or waste material. To make such a system feasible, it was necessary to develop the appropriate sensors—pin-hole detectors, x-ray and plating thickness gages, and surface inspection equipment for detecting whether any blemishes or flaws exist on the surface of the moving strip.

Similar equipment can be—and is being—applied to a hot strip mill. Progress in the basic metal area of the steel plant is also under way, but speed of development has been retarded by the lack of necessary sensors for determining key variables such as the composition of the "in-process" materials.

3. *Program Control Systems*

The first card program control system in the steel industry, installed on a reversing roughing mill in 1956, automatically positions the horizontal work rolls as the ingot is reduced during each of the rolling passes. The latest equipment, however, will perform all the necessary mill setup functions. It will perform horizontal and vertical roll and side-guard positioning, determine forward or reverse direction, and provide proper speed relationships of the mill and the auxiliary drives. A card for such control is shown in Figure 9.

Two advantages result from program control: 1) production is increased by reduced setup time, and 2) a more uniform product is obtained by programming the habits of the best operator.

Here is how the control works on a reversing mill, Figure 10. After an operator brings an ingot on the Run-in Table, he pushes a button to cause the first pass information to be read from the card. This information will position the rolls to the desired position: the mill then automatically starts forward at slow speed. As the

ingot reaches the "forward-speedup" detector—a detector using a solid-state photo-voltaic cell to sense the infrared emission from the incandescent ingot—the mill will accelerate to the programmed speed. When the "trailing edge" of the ingot leaves the "forward slowdown" detector, the mill automatically decelerates, and as the "trailing edge" passes the "forward-stop" detector, the ingot is immediately stopped on the far side of the mill.

The next pass information is then read from the card to position the work rolls, and the mill starts in the reverse direction under the control of the "reverse" directors.

For position control, the mill uses a 400-cycle synchro system (Figure 11). The position code converter (*A*) converts the binary-coded card reader signal to the decimal equivalent. The synchro comparator (*B*) produces a signal proportional to the difference between the desired and the actual roll position. This signal is amplified by error amplifier (*C*) and the output amplifier (*E*) to supply excitation for the magnetic amplifier amplidyne adjustable voltage screwdown control. The null sensor (*D*) disconnects this excitation and sets the associated brakes when no error signals exist and the screws have reached the final position. Built-in test equipment was incorporated with the Reference Test (*F*) to check circuit continuity of (*A*) and (*B*), and with the Amplifier Test (*G*) to provide test signals for (*C*), (*D*), and (*E*).

The equipment is fully transistorized and uses static switching devices where possible. It has been sectionalized both electrically and mechanically to simplify maintenance. Figure 12 illustrates the functional panel arrangement.

A much larger program control panel, approximately 100 ft long, is now being installed on a completely automatic structural mill—the most extensive program control supplied to-date to the steel industry. In addition to individually programming each stand of this multi-stand mill, the equipment will automatically manipulate and transfer the metal from stand to stand until the finished product is obtained. Input signals are received from three static card readers and are channeled by the three program control centers to the sequencing and regulating control panels (approximately 1,000 ft long) for the numerous motor drives involved.

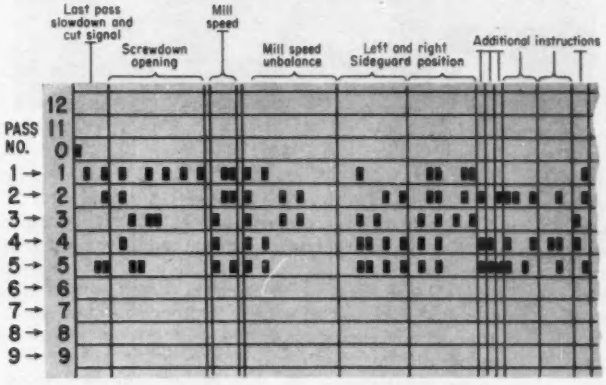


FIG. 9. Punched card for program control.

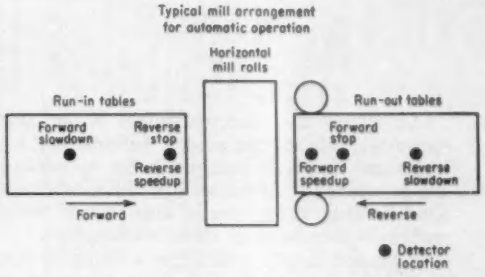


FIG. 10. Layout of detecting units for automatic operation of reversing mill.

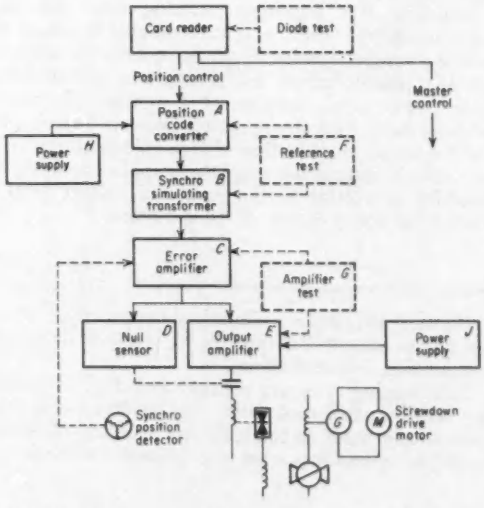
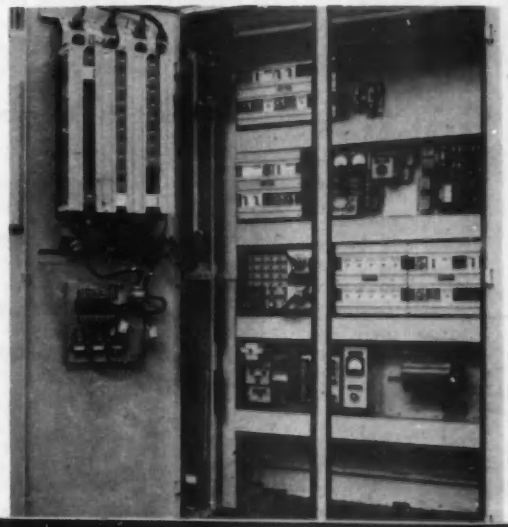


FIG. 11. Program control system.

FIG. 12. Control panel. Each section coincides with the corresponding electrical block and can be easily removed by disconnecting plugs to reduce mill down-time periods.



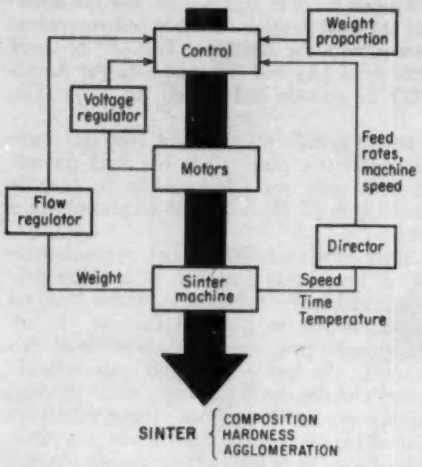


FIG. 14. Director control system for sintering machine.

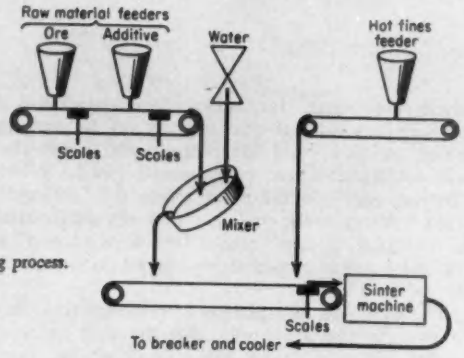


FIG. 13. The sintering process.

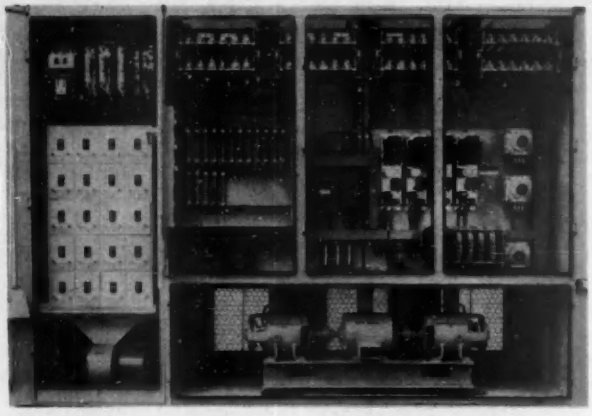


FIG. 15. Packaged control panels.

4. Director Systems

An all-inclusive director system is one that simultaneously collects the process information to provide command signals by computing the optimum sequencing of events from relationships of the process variables. One limiting factor usually turns out to be a lack of sufficient knowledge of these relationships.

A limited director system for a sintering process controlled the production of the sintered ore by regulating the "burn-through point" or the point where complete combustion of the ore occurs in the sinter machine (Figure 13). Machine efficiency was optimized by calculating, with a computer, the amount of material feed rate from the "mixer" necessary to delay the "burn-through point" until just before the sinter left the machine.

If complete combustion occurs too far toward the front, the machine is being used inefficiently. If it happens too late, complete combustion of all the material may never actually occur. As the material feed rate is varied, feedback regulators adjust the speed of the raw material feeders supplying the machine to maintain a constant material level.

Once the material feed rate has been set, it is necessary to maintain the composition of the mix by regulating the exact flow rate of the ore, additive, and hot fines feeders.

Figure 14 shows how the control system is operated from actual measures of weight, temperature, and time of the material being processed. Of course, before a complete director system can be supplied it will be necessary to directly sense the composition and the texture of the sinter product to automatically set machine speed, temperature, proportion by weight, process time, and other variables. These quantities are presently set by the operator because there are no suitable sensors.

Sampling type regulators utilizing static switching units as interval timers were incorporated to adjust the various conveyor speeds. Packaged control panels (Figure 15) provide power for the various motor drives. Each power supply consists of a number of drawout modular units with the necessary protective equipment and the proper combination of high voltage silicon rectifier cells. A three-phase magnetic amplifier converts the incoming ac voltage to the proper dc voltage level to control the speed of the dc drive motors.

Evolutionary Progress

The progress toward a completely automated steel plant will be evolutionary—a step-by-step and process-by-process evolution. Each phase must be planned so that each investment made in equipment will not only provide an immediate step forward but will also permit advancement toward more complete automation at a future date. The scope of the control systems supplied to the steel industry is widening; the most effective control system must utilize the very latest choice of circuits, components, and techniques.

Data logging, program control, and director systems are heavily overlapped with the modernization that must also be made to the basic feedback control system to obtain optimum use of the process machinery.

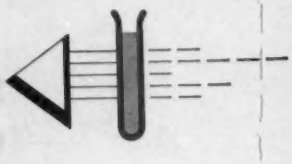
Selecting Control Devices for Human Operators

GEORGE A. PETERS and STAN MICHELSON
Psychological Research Associates, Inc.

This simplified chart is intended as a design guide. While only the more common control devices are listed, others may be more appropriate for certain applications due to design peculiarities.

TASK REQUIREMENTS	TASK EXAMPLES	CONTROL DEVICES	COMMON APPLICATIONS	NECESSARY DESIGN FEATURES FOR MANUAL CONTROL DEVICES	HUMAN FACTORS IN APPLICATION OF MANUAL CONTROL DEVICES
SELECTION BETWEEN TWO ALTERNATIVES	System activation	Toggle switch (two-position only)	Equipment ON—OFF, or subsystem START—STOP	Flip type, definite snap action contact, sufficient lever displacement for easy visual identification of position.	Vertical orientation preferred. ON position should always be UP or to the RIGHT. Use a green pilot light to indicate when circuit is energized. Switch should move toward light to the ON position.
	Momentary contact—high frequency of use	Pushbutton type (A) push = on, release = off	Signal button or typewriter key	Should be color-coded as necessary. Should have a definite feel and audible click when circuit is activated. Concave surface to reduce finger slipping and irritation with continued use. Low force and high pretravel are usually desirable.	Emergency stops should be red and 1 in. minimum diameter. Flush or recessed mounting recommended to reduce accidental activation.
	Extended contact	Pushbutton type (B) push-release = on push-release = off	Foot or elbow pushbutton		
	"Lock-on" contact	Pushbutton type (C) push-release = on another button push-release = off	Motor start switch		
SELECTION BETWEEN THREE OR MORE CONTROL POSITIONS	Channel selection	Rotary selector switch	Function selector or range switch	Mechanical end-stops and detents with an audible click to aid in positioning. The number of positions should be minimum (never over 24). Pointers should be tapered and short to reduce reading errors.	Clockwise movement should result in numerical increase. No switch position should be located 180 deg. from another position, since this increases the chance of erroneous readings.
PRECISE ADJUSTMENT OVER A WIDE RANGE	Align, change, or adjust a continuous variable	Knob	Tuning controls, gain controls, zeroing or null controls	Small knobs should be knurled. Large knobs should have pointed serrations. All knobs should be secured by two set-screws.	Knobs should be below or to the right of scales, and on the concave side of curved scales. Indicator pointers should minimize perceptual parallax.
FORCE APPLICATION	High rate of turning over large distance	Crank	Manual tracking controls	Grip handles should rotate about their own axes (spinner handles).	Clockwise rotation should result in an increase in the controlled function.
	Foot activation	Pedal	Braking or steering controls	Spring should support weight of foot in null position. Pedal should return to null position when force is removed. Non-skid surface for face of pedal.	Used to unburden hands for prolonged force application. Not more than two pedals for each foot.
	Rapid linear displacement or multidimensional movement	Lever	Combination direction and rate controls	Lever handles should be shape-coded. Lever arm displacement arc should not be greater than 90 deg. and should permit convenient arm reach.	Should be located on median plane of body or in front of activating arm. Elbow, forearm, or wrist supports should be provided. Detents for discrete adjustments.
	Rotary forces, slow rate of turn: (A) Two-handed force application with continuous vigilance or feedback (B) Two-handed force application without feedback (C) One-handed force application	Handwheel	(A) Steering wheels (B) Very large valves* (C) Small valves	For two-handed vigilance operations, the operating arc should be less than 120 deg. The gripping surface should be indented or knurled. A spinner handle may be added for whirling. The handwheel may be combined with pushbutton controls.	Clockwise direction of handwheel should be associated with an increase in the visual display (dial) or function, EXCEPT FOR VALVES*. For vigilance tasks, no portion of handwheel should interfere with the operator's vision.

*NOTE: Valves conventionally turn clockwise for OFF or CLOSE. This is contrary to the general principle for control-display relationships. Furthermore, such valve action may increase or decrease the function or process affected. Therefore, it is vitally important to adequately label all valves.



USING K-CAPTURE X-RAYS
to analyze products in the plant

The *K*-capture process generates X-rays as a result of the radioactive decay of an isotope source. Physicists have known about this process for many years, but only within the recent past has the *K*-capture X-ray been used for analyzing liquid and gas streams in the plant. Author Beerbower first reviews the *K*-capture process, describes equipment design in detail, and discusses sampling considerations. He then shows how the equipment has been successfully used for measuring ammonium chloride content in scrubbing tower wash water, and for determining calcium (sulfated ash) content in the manufacture of petroleum products.

ALAN BEERBOWER
Esso Research & Engineering Co.

X-ray absorption determines the concentration of an element in a liquid according to atomic species, not, as is characteristic of lower-energy (radio through ultraviolet) radiations, according to atomic arrangement in molecules. The lack of monochromatic sources, which held back development of the X-ray absorption technique, has been partly overcome by the increasing availability of radioisotopes of suitable characteristics. The nonspecific nature of the method can be dealt with by limiting X-ray absorption to applications in which the process variables of composition fall within a known pattern. Fortunately, this includes the majority of cases; it is rare that a plant stream suffers from the presence of unexpected elements. The usual problem is one of determining the percentage of an element, or of a group of elements in fixed ratio, in the stream.

The K-capture process

At the present time, the *K*-capture process of radioactive decay seems best suited to in-plant analysis of liquids. (Bremsstrahlung radiation offers some interesting analysis possibilities.) The name *K*-capture as a source of X-radiation derives from the capture by the nucleus of one of the two innermost or *K*-shell electrons, resulting in transmutation of the atom into the next lower element in the periodic table. The empty space left by this electron is then filled by another electron, usually from the *L*-shell. The excess energy is radiated as the characteristic excitation of the new atom. The capture and radiation process is shown in Figure 1. The radiation thus produced is truly X-ray since it originates in the electron shell. Gamma rays, which are indistinguishable from X-rays except at the sources, originate in the nucleus.

The X-ray produced by *K*-capture is essentially monochromatic. Actually, there are two components present, some of the empty spaces being filled from the *M*-shell. This produces K_β radiation, slightly more energetic than the K_α from *L*-electrons but also less intense. For an iron 55 source, the K_α accounts for 90 percent of the radiation.

Underlying X-ray absorption analysis is the fact that the X-ray emitted by an element is strongly absorbed by the elements slightly below it in atomic number but only moderately absorbed by itself and the elements above it. This is the absorption edge effect. Thus, the radiation from iron 55, which is actually emitted by its decay product manganese 55, shows the mass absorption coefficients (μ/ρ) illustrated in Figure 2. The coefficient is part of the Beer-Lambert law of absorption:

$$I/I_o = e^{-(\mu/\rho)\rho x c}$$

where I_o = intensity without the absorber
μ = linear absorption coefficient
x = cell depth
c = concentration
ρ = density

The nature of the relationships shown in Figure 2 makes it particularly easy to determine, for example, highly absorbing calcium in the presence of iron, nickel, or cobalt; or highly absorbing sulfur in the presence of carbon and hydrogen.

While iron 55 is a good source of X-radiation for analyzing calcium and sulfur, its use (Figure 2 again) results in a loss of sharpness of the absorption edge at chromium, between vanadium and manganese. For pure K_α iron 55 (2.10 Angstroms), the absorption at chromium would be 65, but the presence of 10 percent of the K_β radiation (1.91 Angstroms) causes a mixed ray with a resulting absorption at chromium of 100.

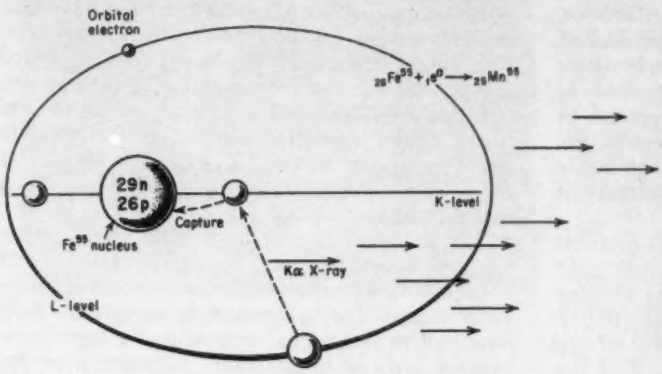


FIG. 1. Mechanism of K-capture. (Courtesy Tracerlab, Inc.)

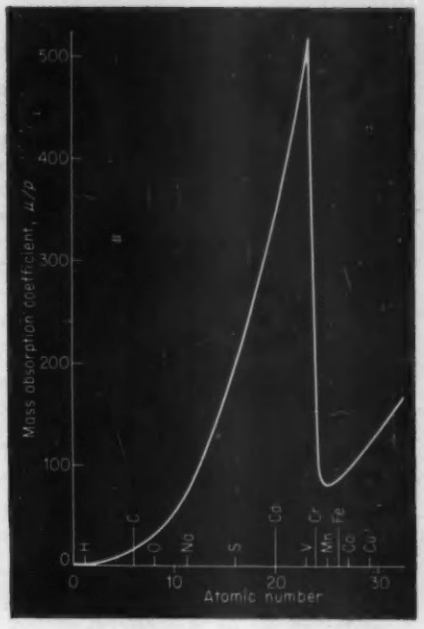


FIG. 2. Mass absorptivity of elements for iron 55 K-capture X-ray.

Figure 2 shows only the mass coefficient absorption curve for an iron 55 radioactive source. Other isotopes, like those listed in the table, have similar curves but with the absorption edge displaced to the left or right according to atomic number of the particular isotope. Most of the isotopes in the table emit various amounts of gamma radiation (iron 55 is often contaminated with iron 59 emitting gamma rays at 1.2 million electron volts) which can be discriminated out by means described later in one of the applications of K-capture radiation.

The table shows that each isotope strongly absorbs a group of neighboring elements of atomic number lower than that of the source. Within this group, the specificity of analysis is low. However within source atomic numbers 19 through 30 there is considerable overlap in the strongly absorbing atomic numbers, which permits some choice of source used for determining a particular element. Furthermore, the overlap, plus the absorption edge effect, permits the development of an analyzer specific to one element. For instance, a specific analyzer for vanadium can be constructed using two sources, Mn 54 and Fe 55. Vanadium (atomic number 23) has minimum absorption for Mn 54, whose absorption edge is to the right of vanadium, while vanadium has maximum absorption for Fe 55, whose absorption edge is just to the left of vanadium (see Figure 2). An analyzer designed in this manner could scan the stream successively with two complete absorption systems, and report the vanadium concentration in terms of the difference in readings.

The composition of the stream in regard to other constituents may or may not be important, depending on the relation of the other elements to those being measured. Three cases are readily handled by K-capture X-rays:

1. All elements except the measured variable have small mass absorption coefficients for the radiation used.

2. There are elements of high absorption present, but their concentration is constant.

3. Two or more strong absorbers vary in constant ratio; this complex is the variable to be measured.

If none of these criteria is met, it is best to seek a method other than X-ray absorption. For example, the measurement of sulfur in the presence of a variable amount of lead has proved impractical, but at a shorter wavelength lead can be measured almost independently of sulfur.

Equipment

The only unit now available commercially (Tracerlab, Inc., Model PIP-4) is primarily designed for laboratory use; it is not rugged enough for the average plant. That is why the problems encountered in using this instrument arose mainly in transferring it to a plant application. The source is iron 55 and the normal use is determining 0.05 to 2.7 percent sulfur content. There was also a question as to whether the source was sealed adequately for plant use. The cell was not equipped for continuous flow (though a continuous flow cell is now available)

LONG-LIVED K-CAPTURE RADIOISOTOPES

Atomic number	Element	Atomic weight	Half life, years	Mev gamma radiation	K wavelength A°	Atomic numbers strongly absorbing
19	K	40	4.5×10^9	1.5	4.30	8–17
23	V	49	0.90	None	2.75	12–21
25	Mn	54	0.85	0.84	2.29	14–22
26	Fe	55	2.94	None	2.10	15–23
28	Ni	59	10^5	None	1.79	19–26
30	Zn	65	0.69	1.12	1.54	21–28

and appeared to be unsuited for moderate pressures because of the thin beryllium windows; furthermore, a specific design for viscous materials was desired. Accordingly, a complete redesign was undertaken: the mechanical positioning arrangement used to compensate for isotope decay was eliminated in favor of electrical compensation; and certain features which made the laboratory instrument highly accurate but too cumbersome for a plant instrument were also eliminated.

Figure 3 shows the modified unit, which features: good fluid flow in a straight path to provide rapid displacement of sample; ease of cleaning by flushing or disassembly; pressure tightness to 50 psig; extreme compactness; and inherent shielding so that no one can receive radiation without removing part of the equipment.

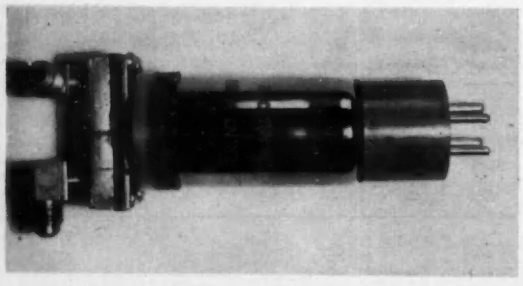
These improvements were accomplished by combining the source holder, sample cell, and Geiger tube mounting into an integral sandwich of five layers of metal and plastic. The base plate serves as source holder and also as sample entrance and exit ports. Stainless steel is recommended for corrosive service. The source consists of irradiated (in a cyclotron or reactor) metallic iron plated on a copper disc $\frac{3}{8}$ in. in diameter. It was sealed onto the plate and covered with polystyrene applied as semipolymer plus catalyst and hardened in place. This assembly withstood a leak test of boiling for one hour in $\frac{1}{4}$ percent ethylene diamine tetra-acetic acid, during which time the solution picked up less than 0.05 microcurie of radioactivity.

The cell is formed from plastic sheets. The first is Mylar, 7.5 mils thick, perforated for the sample inlet and outlet. The second is Lucite, $\frac{1}{16}$-in. thick, slotted to form the sample chamber. This can be interchanged with chambers of other thicknesses for special purposes. A third Mylar sheet of 7.5 mils covers the cell. The cell volume is 0.34 cc. A cover plate of brass, $\frac{1}{16}$-in. thick, applies the pressure of the screws which hold the unit together. Finally, a threaded adapter permits screwing the Geiger tube (Tracerlab TGC-3) directly onto the blocks.

Calibration of the commercial equipment is done in the following steps:

1. Determine background radiation by filtering out X-rays with a thin copper sheet between sample cell and Geiger tube. This count rate, which includes any gamma radiation from the source, is subtracted from all other readings.

FIG. 3. Liquid cell construction.



2. Put in the cell a sample free of the component to be determined but otherwise a complete product, and measure the radiation without the copper sheet. This count rate minus the background is plotted as 0 percent concentration on semi-log graph paper.

3. Put a well-analyzed sample of known concentration of the plant stream in the cell and measure it. The reading minus background is plotted at the known percentage and a straight line drawn through the two points.

This procedure can be substantially shortened by electrical techniques. A scintillation detector plus a single-channel pulse-height analyzer on the rate meter reduces the background to a negligible level compared to the normal output, and a logarithmic recorder gives a linear scale. Compensation for isotope decay with time is simply a matter of making a corresponding increase in recorder gain. After the slope is established, a single calibration, using either analyzed product or product free of the measured component, may be made, setting the recorder electrically to the correct reading.

The unit just described in detail is designed to handle viscous liquid samples. For thin liquids, a simple modification of the PIP-4 in which a continuous flow cell was used in place of the regular one has given satisfactory service in a pilot plant. A more specialized type, for gas streams, has a 2-in. cell depth for analysis of sulfur content in H_2S. Various suppliers of commercial nucleonics equipment have expressed willingness to build special units to customers' specifications.

Sampling considerations

The usual rules of continuous sampling must be followed. No special filtration problem exists; an occasional particle of foreign material merely causes a momentary increase in noise, which is already inherently high in this type of device. On the other hand, anything tending to plate out in the cell (such as oil drops) must be removed. The flow rate can be high, but any short-duration peaks in concentration that may occur will be averaged out on the record, since the rate meter will normally have a time constant of about 10 sec (the time for a reading to decay to 1/e or 36.8 percent on cessation of the signal). This averaging effect is intimately connected with the statistical nature of radioactive decay, and is difficult to overcome.

The standard deviation of the count rate is $\sqrt{N}$ where N is the number of counts arriving during a time constant interval T at an average count rate R. Hence:

Coefficient of variation $\sqrt{N}/N = 1/\sqrt{RT}$

A coefficient of 1 percent would be desirable. This leads to $T = 10{,}000/R$. Thus, a count rate of 60,000 counts per min would be required for a 10-sec time constant. The usual source of only 4 millicuries supplies about 10,000 counts per min with the sample in the cell and so yields a usually accept-

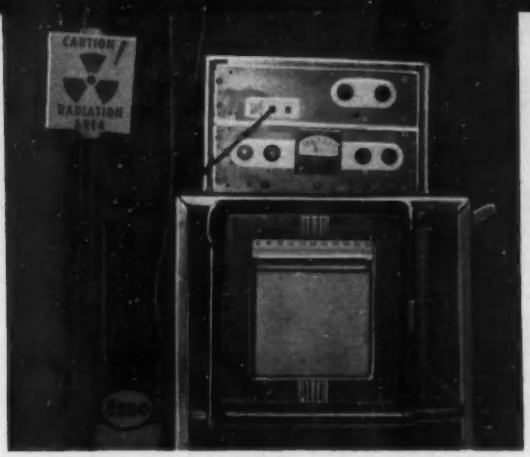


FIG. 4. Liquid cell installation.

able coefficient of variation of 2.5 percent. In terms of concentration, which corresponds to the logarithm of the count rate, this is only plus or minus 0.05 percent, or 1 percent of the average value of 5 percent of the measured element in a typical case.

A smaller coefficient of variation is possible by using a stronger source to increase the count rate. (Using a more sensitive detector is not very helpful because detection is already quite efficient.) Decreasing sample cell length will also increase the count rate, but at a serious sacrifice in sensitivity. The optimum cell length is determined by the maximum signal/noise ratio ($S/N = \Delta I/\Delta c\sqrt{I}$). It can be shown that this occurs at a transmission of $1/e^2$ or 13.6 percent, based on the transmission of the fluid free from the measured element. The optimum cell length is determined by setting the I/I_o in the Beer-Lambert equation to 0.136 and solving for x. The cell length of $\frac{3}{16}$ in. was selected on this basis; it gives 13.2 percent at standard conditions. A cell $\frac{1}{4}$ in. long on the same sample gave only about one-third the sensitivity.

Since the time constant of the rate meter already limits the dynamic response of measurement, the sample flow rate should be fast enough so as not to add to these limitations. This means, for the system described, that the minimum sample flow rate is one cell change (0.34 cc) in 10 sec, or 0.034 cc per sec. The minimum flow rate should, of course, be exceeded to make the sample cell time constant somewhat less than the rate meter time constant, and to minimize dead time in the line.

The response to changes in concentration depends on the weight of active absorber per unit volume; therefore, changes in density due to sample pressure and temperature are significant. With liquid samples, the correction for thermal expansion of the cell and its contents amounts to about 1 percent (of the reading) per 9 deg F change, an indication of the extent of temperature control required to stay within the limits already imposed. The cells themselves are pressure-sensitive, due to the thin windows employed. The liquid sample pressure should not vary more than plus or minus 5 psi. The gas cell mentioned previously is extremely pressure-sensitive, and is controlled to plus or minus 1 mm of mercury.

Plant applications of K-capture X-ray

The redesigned liquid cell described above has been used in three cases calling for continuous analysis. One of the cases involved a lubricant consisting of a fluid dispersion of a calcium soap in SAE 40 oil. Control was by the sulfated ash content, a measure of the product's calcium content. The absorptive elements, calcium and oxygen, were in fixed ratio to each other, while sulfur content was constant for a given shipment of oil. This product is made continuously in a proportioning system. Sample flow through the cell, using a small metering pump delivering at a constant pressure of 4 psi, was at the rate of 25 grams per min. Temperature was controlled to 135 plus or minus 5 deg F. A TGC-3 Geiger counter, connected to a rate meter, was mounted as shown in Figure 4, with a recorder coupled to the output through a potentiometer.

Weekly calibration consisted of determining a blank reading on the SAE 40 oil to eliminate the effects of changing sulfur content, Geiger tube sensitivity, and source decay. This reading (about 45,000 cpm) was used to set the recorder at a "set-point" with an 0.1 multiplication factor. The actual sulfated ash content of the lubricant was then read off a special scale, which takes into account the essentially constant gamma-ray background noise of 600 cpm. The calibration curve from which the scale was derived is based on the results obtained in triplicate chemical analyses. In general, these plant instrument readings were more accurate than single laboratory determinations. An alarm system indicated deviations from the specified ash content.

Another application involved monitoring the wash water that removed ammonium chloride accumulations from the bubble cap section of a scrubber tower. At the start of the wash, the water had a concentration of about 6 percent of ammonium chloride, which in a few hours dropped to less than 0.1 percent. When the ammonium chloride content dropped below a predetermined concentration, the washing operation was stopped; this increased tower operation efficiency and saved the cost of wash water.

The cell with a $\frac{1}{4}$-in.-long path was used because of the high absorption of the oxygen in the water. The calibration was made with pure water and by reading percent NH_4Cl off a calibration chart from the percent transmission. It is necessary in this application to separate thoroughly any oil from the sample water stream; otherwise oil drops will cause serious interference due to their higher transmission of X-rays. This made a large settling vessel in the stream and continuous oil removal necessary. Even with this precaution it was found that oil presented a serious problem and filtration was required to provide continuous monitoring.

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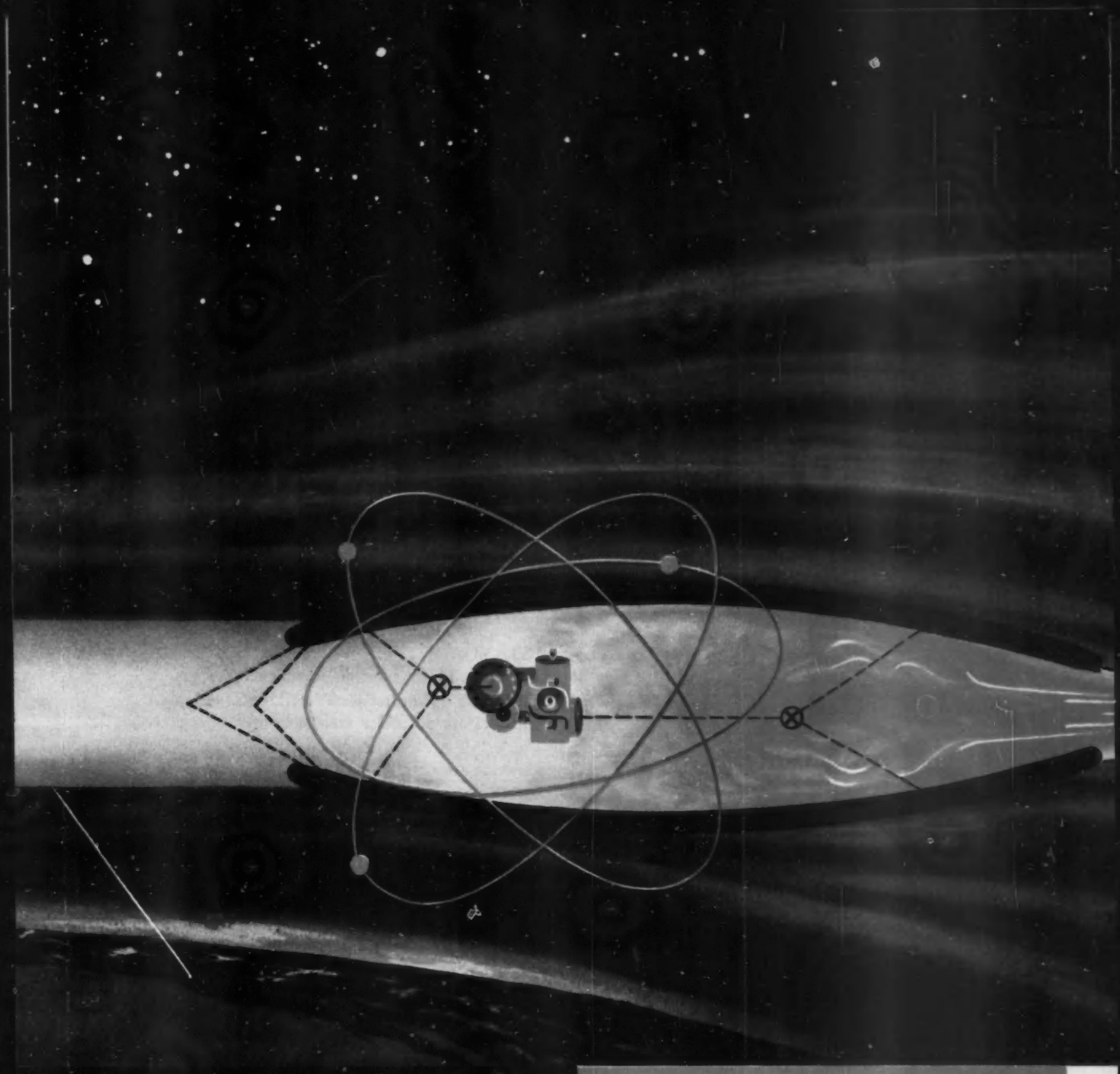
Roy E. Marquardt, *President*



C & A Division engineers made many contributions to the "state of the art" when they developed the fuel control system for the supersonic ramjet engine.

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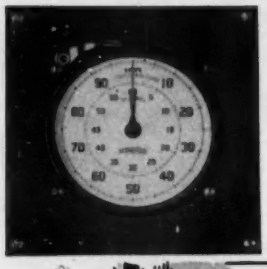

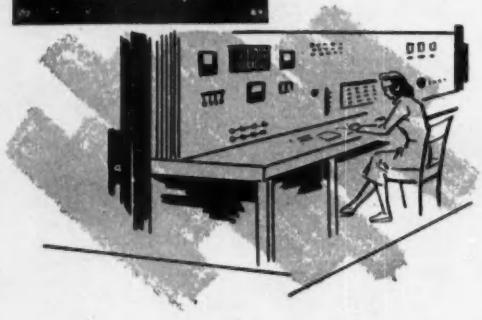

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SM-60	1/100 min.	60 min.	±.002 min.
S-10	1/10 sec.	1000 sec.	±.02 sec.
S-6	1/1000 min.	10 min.	±.0002 min.
S-1	1/100 sec.	60 sec.	±.01 sec.
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Logical Control of Sampling Saves Computing Time

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Radio Corp. of America

Many of the systems now in use for sampling system variables, both military and industrial, suffer badly from inflexibility. A need exists for a way to note that a certain data source is inactive and that its sampling could be skipped with no loss of information. Time could be saved if many skips are encountered, provided that the interrogation rate, to sample or not to sample, is very fast compared to the rate determined by the minimum time needed for sampling.

A system incorporating these features has been operating for more than a year in a large-scale check-out system for a missile guidance radar network. The sampled data in this case are to be recorded, and subsequent computer time is saved by first reading all data sources to be sampled simultaneously into storage registers, Figure 1. Thus, all samples in a given sampling cycle are referred to the same time base, and the computer need not interpolate the information it receives. This can save as much as 15 percent of the overall computing time. The sampling instant is controlled by a read pulse generated at the beginning of each sampling cycle.

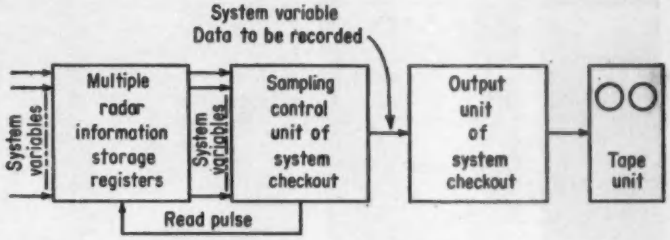


FIG. 1. All data sources are read simultaneously into storage registers, then sampled into permanent tape store.

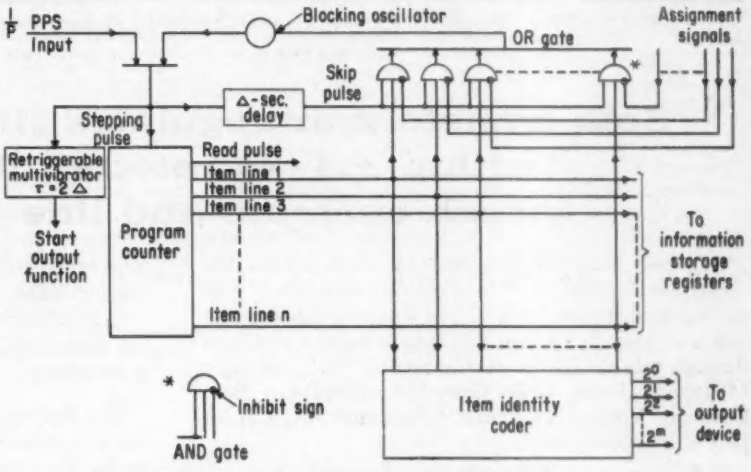


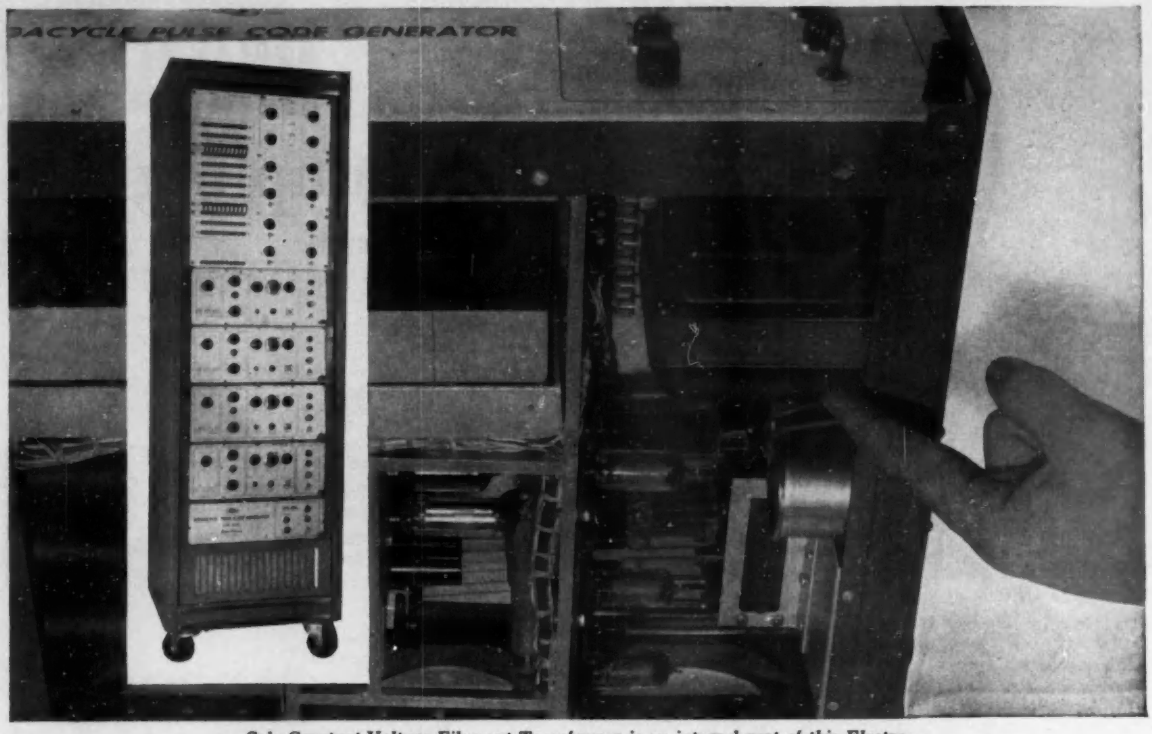
FIG. 2. Sampling control unit takes p sec to record one data item and make maximum number of skips at 1/Δ pps. Complete sampling cycle takes only 3p sec if three items are assigned.

The sampling control unit is shown in the block diagram of Figure 2. The program counter cycles through n outputs, each output representing one of n system variables, called "items", being considered for sampling. The counter is stepped either by an external source of periodic pulses or by skip pulses generated within the sampling control unit. In each period p of the external stepping pulses, there is one execution of the intended output function for the radar application (recording of the sample). This period p must be made long enough to execute the longest output function, and yet short enough to satisfy the minimum cyclic rate for the sampling. For example, if the minimum time to record a sample is 1 millisec and the minimum sampling rate of 13 system variables is 10 samples per sec, then $1 \leqq p \leqq 7.69$ millisec.

Each item line from the program converter alerts its information storage register in the event that it is selected to perform the output function. Each item line also feeds the item identity coder and addresses a skip gate in the skip circuits.

In the radar check-out system, assume that there are four radars, and that the three variables of elevation, azimuth, and range must be sampled from each of them. If radar 1, say, is inoperative because it is on standby or is mulfunctioning, its data need not be recorded. Radar 1 is thus not assigned for recording, and will not produce the assignment signal needed to block the next skip pulse. The counter will then skip to item line 4.

The complete skipping process goes as follows: the skip pulse is first generated by transmitting the external stepping pulse through the Δ-second delay line. This skip pulse is then fed to all the skip gates in parallel. Though many skip gates may have permissive control signals due to unas-



Sola Constant Voltage Filament Transformer is an integral part of this Electro-Pulse, Inc. Megacycle Pulse Code Generator. It provides regulated filament voltage for reliable operation of the equipment and for full life of its electron tubes.

Sola transformer regulates filament voltage within ±1%--protects tubes from inrush currents and line transients

Fluctuations in supply voltage for electron tube filaments can be costly . . . in shortened tube life . . . in substandard performance . . . in equipment downtime. Electro-Pulse, Inc. solved its filament voltage problems through this straightforward approach: the company's Megacycle Pulse Code Generator includes a Sola Constant Voltage Filament Transformer built-in as part of its power supply.

This versatile unit does the step-down job of a conventional transformer and it also regulates the filament supply — a task that ordinary filament transformers don't pretend to do. Filament voltages are stabilized to within ±1% even with line voltage variations as great as ±15%. Its current-limiting characteristic protects tubes from cold inrush currents upon starting—as well as from line transients. It is a simple, reliable static-magnetic regulator with automatic and virtually instantaneous action. Variations in input voltage are usually corrected within 1.5 cycles. There are no tubes or moving parts, and no manual adjustment or maintenance is necessary.

The filament voltage regulator illustrated is only one of a complete line of Sola Constant Voltage Transformers having wide application in electrical and electronic devices. They include such special types as harmonic-free, plate-filament, and adjustable output units—all provide the benefits of regulated input voltage. More than 40 ratings of these compact, economical regulators are available from stock, and Sola manufactures custom-designed units (in production quantities) to meet special needs.

For complete data write for Bulletin 26C-CVF-269

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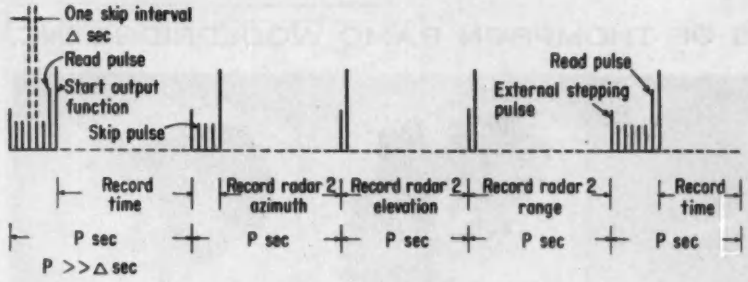

FIG. 3. Typical timing pattern for program counter (see text).

signed items, the skip pulse is only able to gate through the one that is addressed by its item line—and that gate must receive no item assignment signal. If the skip pulse is gated through, it is reshaped by the blocking oscillator and sent to step the program counter to the next item line in the sequence. This stepping pulse in turn generates another skip pulse. In this way it is possible to skip any number of item lines in succession until one is reached that is assigned.

The Δ delay should be extremely short compared to the period p, to make available as much of the period p as possible for the execution of the output function. Thus, the delay line should be as short as possible consistent with proper circuit behavior.

To start the output function, (i.e., record an assigned sample) one practical scheme would be to delay it always for n Δ sec, to make the maximum number of skips in succession. In a second scheme, the skip pulses would set a retriggerable one-shot multivibrator whose period is slightly greater than one skip period. Then the multivibrator could recover only at the end of a series of skip pulses, that is, after an item line is properly selected. Differentiation of the multivibrator output produces a pulse of the correct polarity every time the multivibrator recovers, and this is a satisfactory start-output-function pulse.

The timing pattern in Figure 3 shows all the pulses in one sampling cycle when only radar 2 of four radars is assigned. The read pulse at item line zero causes all data sources to be read into the information storage registers, while p sec are taken to record the time of sampling. All samples in the cycle are referenced to this time.

Force Balance Computes F-104A's Speed

LEONARD KENDY, U.S. Science Corp.

The unique trigonometric force-balance mechanism that computes Mach number in the F-104A's new air data computer is also used as the altimeter. The switch is made by substituting a pre-loaded spring for the differential pressure bellows. The technique is applicable in any aircraft.

In the air data computer for the Lockheed F-104A Starfighter, Mach number is computed by a new type of force-balance sensor. Figure 1 illustrates the operating principle.

The sensor is enclosed in a case into which static pressure is admitted. The force plate is mounted in precision bearings, and is free to pivot about the sensitive axis. Rotations about this axis are sensed by a proportional pick-off of the E-core type. The differential pressure bellows is fixed at one end to the instrument case, and at the other end to the force plate. The whole assembly is then statically balanced about the sensitive axis.

A servomotor drives the output shaft, which in turn rotates the bellcrank assembly. This assembly consists of a base plate and a bearing-mounted rocker arm, with an evacuated bellows fixed at one end to the base plate and at the other end to one side of the rocker arm. The other side of the rocker arm carries a preloaded ball bearing which presses against the force plate. The bellcrank assembly is also statically balanced.

In operation, each bellows produces a torque about the sensitive axis. If the algebraic sum of the applied torques is not zero, the force plate will rotate, causing the pickoff to produce an error voltage. This voltage is amplified and supplied to the control phase of a servomotor which rotates the bellcrank assembly until torque

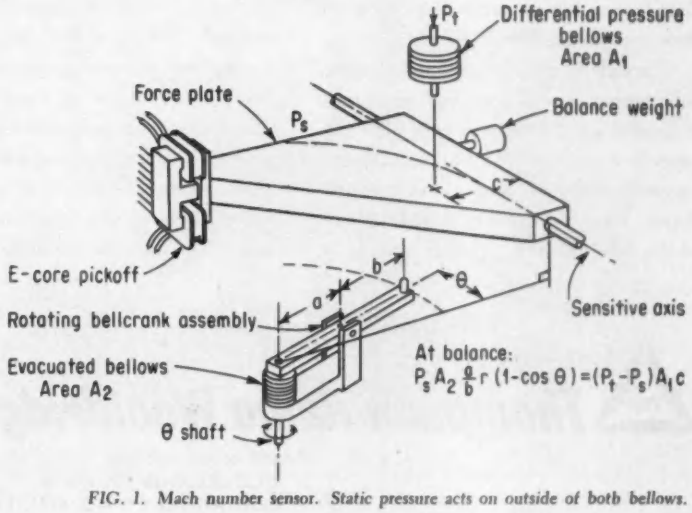

FIG. 1. Mach number sensor. Static pressure acts on outside of both bellows.

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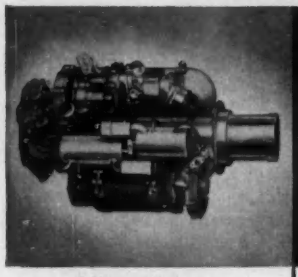
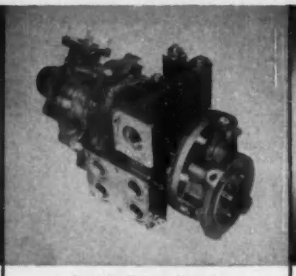
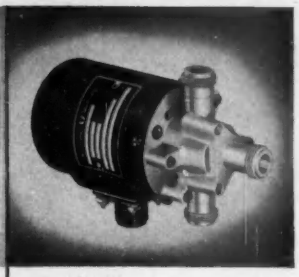


Solid-propellant auxiliary power unit

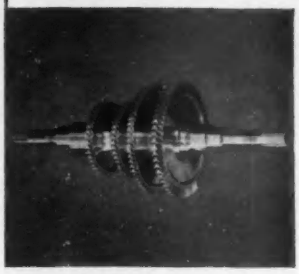
Titanium missile pressure vessel



Combination main and after-burner fuel pump



Coaxial switch



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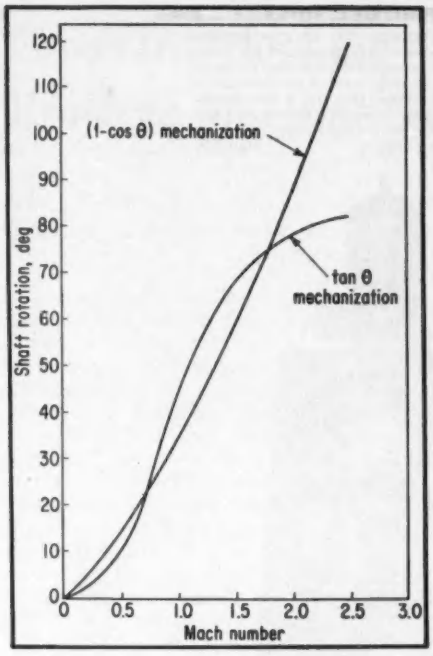
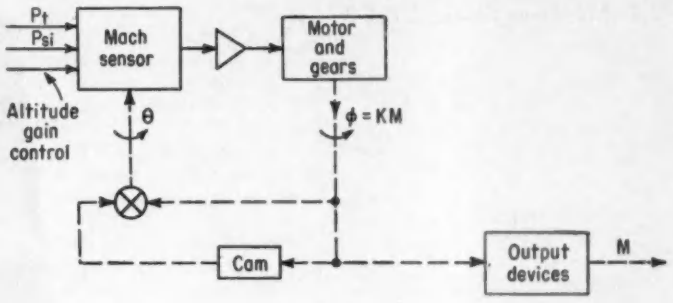


FIG. 2. Relationship between shaft rotation and Mach number for two different types of Mach sensors.

FIG. 3. Error between (1-cos θ) curve and true linear output is added to Mach sensor shaft by a cam and differential.



equilibrium is reached. This mechanization produces the equilibrium:

$$\frac{(P_t - P_{si})}{P_{si}} = K\,(1 - \cos\theta) \qquad (1)$$

The scale factor K is selected so that $\theta = 120$ deg at Mach = 2.5. Since the scale factor is the product of several parameters,

$$K = \frac{A_2 ar}{A_1 cb} \qquad (2)$$

it is not necessary to match bellows areas or hold tight machining tolerances to control its value. The moment arm c of the differential pressure bellows is adjustable, and by moving this bellows, the entire tolerance accumulation can be removed. Similarly, bellows free-length and rocker-arm-length adjustments are provided to trim out other parameters.

The curves of Figure 2 show that primary reason for selecting the (1-cos θ) mechanization is that the shaft rotation vs. Mach number is more nearly linear than the tangent mechanization. There are two other important features of this approach:

- the Mach function is developed over 120 deg of shaft rotation, yielding improved resolution, while gear backlash tolerances can be relaxed.
- the sensor can be scaled for any Mach range from subsonic to over Mach 5.0, while still retaining the nearly linear output, by adjusting the moment arm of the differential pressure bellows.

As Figure 3 illustrates, the servomotor drives a gear and a cam in the process of balancing the sensor. The gear drives one side of a mechanical differential; the other side is driven by the output of the cam. The algebraic sum of these rotations positions the θ shaft. The direct drive is linear with true Mach number, and the cam makes up the difference between the actual function and the linear function. The maximum value of this difference is about 8 percent of full scale, so the required cam contributes only a mild correction, and tight machining tolerances are not needed.

This Mach number computer has proved its ruggedness and reliability by accumulating over 500 hours of operation without shifting its calibration curve. Testing included runs at minus 55 deg C, plus 71 deg C, and shock tests. The Mach operating range is $M = 0.2$ to 2.5 from sea level to 80,000 ft. The accuracy is 5 milli-Machs or ½ percent, whichever is greater. Figure 4 shows this unit.

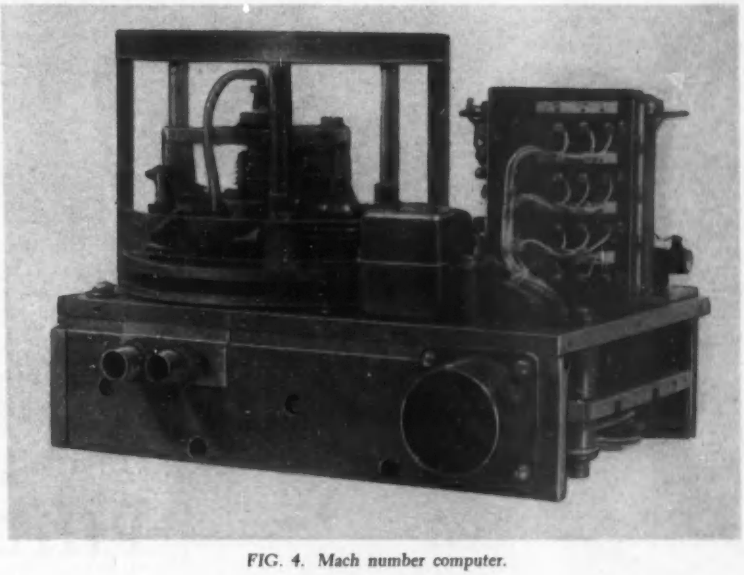


FIG. 4. Mach number computer.

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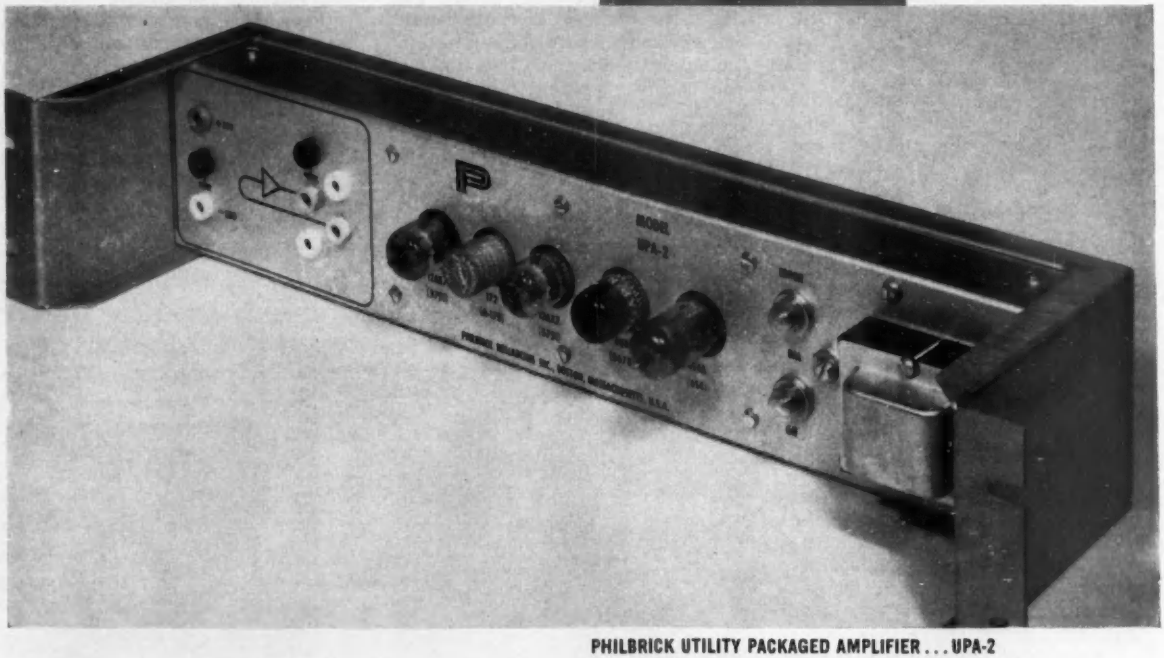

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Cross-Interlocking Clamps Protects Machine Tool

THOMAS CAMERON
Sundstrand Machine Tool Co.

The workpiece holding fixture in a machine tool must be clamped solidly during machining and must be properly released at the end of the machining period. In Figure 1, *LS*-1 indicates the unclamped position and may be used to start a reloading sequence. Very often the workpiece is a rough casting with wide variations in the dimensions to be clamped. With the largest workpiece expected placed in the fixture, *LS*-2 is adjusted to operate on the clamping stroke just before the clamps touch the part; it will then operate throughout the range of part sizes. However, *LS*-2 alone does not indicate that pressure is applied to the part or that a small part is actually clamped.

The pressure switch operates on rising pressure to indicate that pressure is being applied to the clamps, and also protects against hydraulic failures. But since it could close because of a pressure surge at the start of clamping or because of sticking clamps, *LS*-2 is used with it for a reliable indication.

In Figure 2, *CR*-1 indicates that the fixture is unclamped. *CR*-2 gives the clamped indication. Cross-interlocking of *LS*-1 and *LS*-2 gives protection against switch failure, particularly sticking of the operating mechanism. The machine is stopped before the false indication can cause damage.

Fig. 1

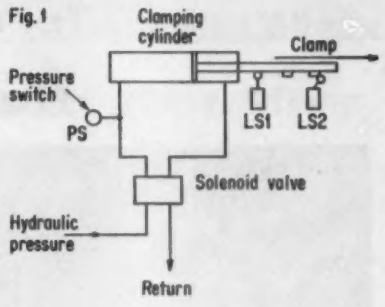
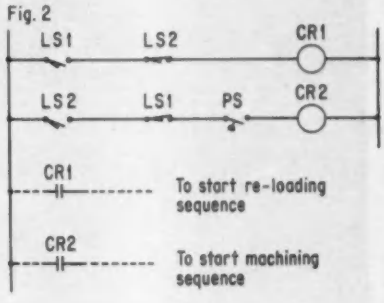


Fig. 2



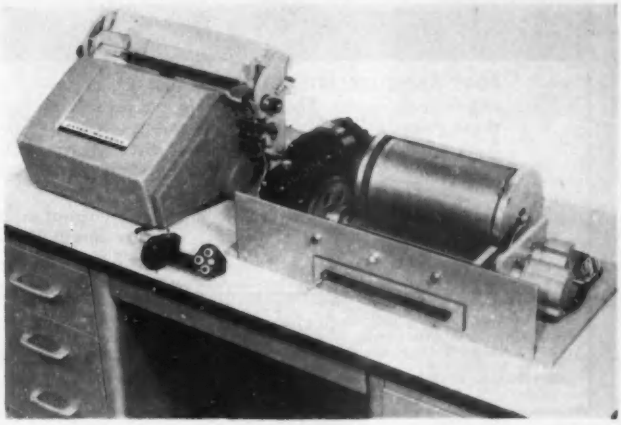
Tube Lengths Recorded Automatically

Datex Corp. has designed and installed a linear encoding system for Pacific Tube Co. that simplifies and makes more accurate the recording of stainless-steel tube-length measurements. Before installation of the unique system, two men stretched the tape along the tube to measure its length, a third man wrote down the lengths which were called out and a fourth typed out the written notes.

Now the bale of tubing to be measured is simply rolled out in a single layer on an inspection table and butted against an end-stop. The operator, who is also the visual inspector, places the end of a small control handle against the other end of the tubing, and presses the "record" button on the handle; instantly, the length is recorded in feet and inches on an automatic typewriter in the office. The total length in a bale or shipment is just as quickly obtained by pressing a "total" button.

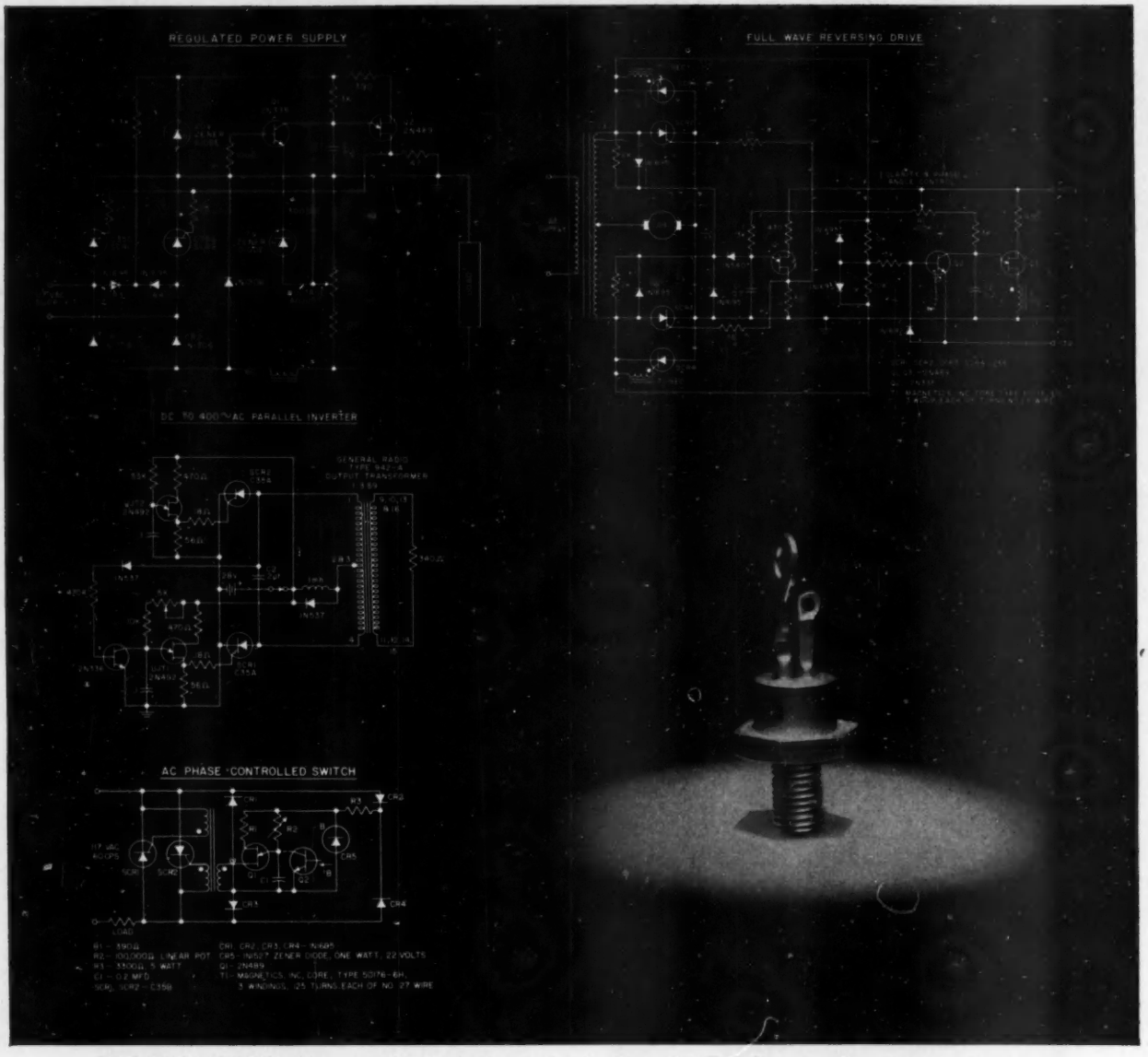
The hand grip is attached to 104 ft of aircraft control cable, which is reeled on an aluminum drum exactly 2 ft in circumference. The drum is geared 5:1 to the encoder assembly, which converts its rotation into feet and inches in the form of a nonambiguous digital coded output. A takeup motor in the encoder assembly keeps the cable under a tension of 5 lb.

The new system can measure and automatically record any linear length from zero to 100 ft in 1-in. increments, within 0.5 in. Duplicate measurements of the same lot will come out within an inch or two of the same value, an unheard-of accuracy in hand measuring. The system assures the customer that he will receive and be billed for the exact footage ordered.



General Electric Semiconductor News

New prices, new circuits for



FOUR BASIC CIRCUITS. Above are four basic designs for the Controlled Rectifier using the unijunction transistor as the firing means. The unijunction is a precision trigger, putting out short, high current pulses. The frequency of these pulses will not vary with the supply voltage or temperature, yet can be variably controlled with a silicon triode from a low level feedback signal. Unijunction firing circuits are easily synchronized with 60 cycle line frequency. In short, the unijunction provides the simplest and least expensive means for precision firing of the Silicon Controlled Rectifier.

General Electric's new silicon medium-current rectifiers, Types 1N2154 thru 1N2160, are ideal as companion devices to the controlled rectifier for reverse-voltage protection and, also, for applications in full-wave circuitry.

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- Frequency converter, current control
- Power switch for automatic temperature control electronic flash
- Reversible motor control
- AC variable speed induction motor
- Dynamic braking
- Light dimmers
- Thyratron replacement for relay drivers
- Pulse width conversion
- High speed printer for digital computer
- Welding control
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- Circuit breaker replacement

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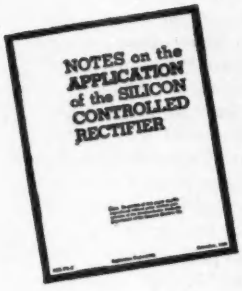
"Controlled rectifiers may revolutionize the electrical industry." This statement was made a year ago by a respected news publication. Since then samples have been studied by hundreds of firms. Many new circuits have been developed which promise important improvements in functions, reliability, simplicity, accuracy and lower cost. In just one year prices have been reduced 75 percent (see chart below). And now, the G-E Silicon Controlled Rectifier is a standard, production-line item, warranted in writing and available at sharply reduced prices.

This is the time for design engineers to exploit the inherent advantages of the Silicon Controlled Rectifier in their circuit designs. Many applications are proved . . . the firing circuits have been refined . . . the product line is stabilized . . . and it makes sound economic sense. Call or write your G-E Semiconductor Sales Representative for complete details. The Controlled Rectifier is also available from many local G-E Distributors.



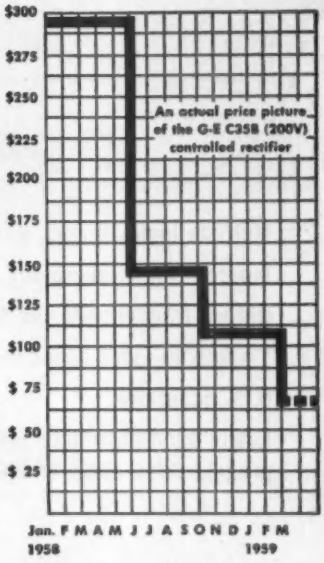
HOW THE G-E CONTROLLED RECTIFIER WORKS. The Silicon Controlled Rectifier is a three junction semiconductor device for use in power control and power switching applications requiring blocking voltages up to 400 volts and load currents up to 16 amperes. Series or parallel circuits may be used for higher power applications.

The G-E Controlled Rectifier's reverse characteristic is similar to a normal silicon rectifier in that it represents essentially an open circuit with negative anode to cathode voltage. The forward characteristic is such that it will block positive anode to cathode voltage below a critical break-over voltage if no signal is applied to the gate terminal. However, by exceeding the forward break-over voltage or applying an appropriate gate signal the device will rapidly switch to a conducting state and present the characteristically low forward voltage drop of a single junction silicon rectifier.

DETAILED NOTES are available on the application of the G-E Silicon Controlled Rectifier, plus reprints of articles that have appeared in technical journals. Write to Section S16359, Semiconductor Products Dept., General Electric Company, Electronics Park, Syracuse, New York.

STEADY PRICE DROP. Since its introduction one year ago, the price of the typical G-E Controlled Rectifier has dropped more than 75 percent. This results from improved manufacturing techniques and volume production. The G-E Controlled Rectifier is now a production-line item, warranted in writing for one year and subjected to the same quality control tests imposed on all General Electric transistors and rectifiers.

The G-E Controlled Rectifier is also available at even less cost (ZJ39L series) for use at 100°C and below, with currents up to 10 amperes.



MAXIMUM ALLOWABLE RATINGS (Resistive or Inductive Load)

	C35U	C35F	C35A	C35G	C35B	C35H	C35C	C35D
Continuous Peak Inverse Voltage (PIV)	25	50	100	150	200	250	300	400 volts
Transient Peak Inverse Voltage (Non-Recurrent<5 millisec.)	35	75	150	225	300	350	400	500 volts
RMS Voltage (V_{RMS}), Sinusoidal	17.5	35	70	105	140	175	210	280 volts
Average Forward Current (I_F)	Up to 16 amperes							
Peak One Cycle Surge Current (I_{surge})	150 amperes							
Peak Gate Power	5 watts							
Average Gate Power	0.5 watts							
Peak Gate Current (I_G)	2 amperes							
Peak Gate Voltage (V_G) (forward)	10 volts							
Storage Temperature	−65°C to +150°C							
Operating Temperature	−65°C to +125°C							

CHARACTERISTICS (At Maximum Ratings)	C35U	C35F	C35A	C35G	C35B	C35H	C35C	C35D
Minimum Forward Breakover Voltage (V_{BO})	25	50	100	150	200	250	300	400 volts
Maximum Reverse (I_R) or Forward (I_S) Leakage Current (Full Cycle Average)	6.5	6.5	6.5	6.5	6.0	5.5	5.0	4.0 ma
Maximum Forward Voltage ($V_{F\ AVG}$)	0.86 volts (Full Cycle Average)							
Maximum Gate Current To Fire (I_{GF})	25 ma							
Maximum Gate Voltage To Fire (V_{GF})	3 volts							
Typical Gate Current To Fire (I_{GF})	10 ma at +1.5 volts (Gate to Cathode Voltage)							

ZJ39L Series—lower cost series with ratings similar to above, but for use up to 100°C maximum, with forward current ratings up to 10 amperes.
ZJ50 Series—a high-current series now in development, and available on a prototype-sample basis.

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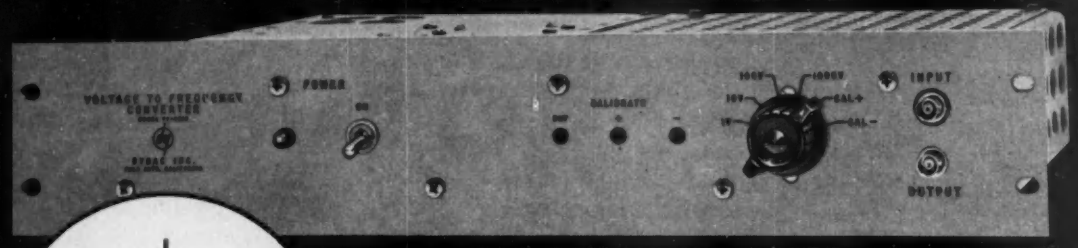
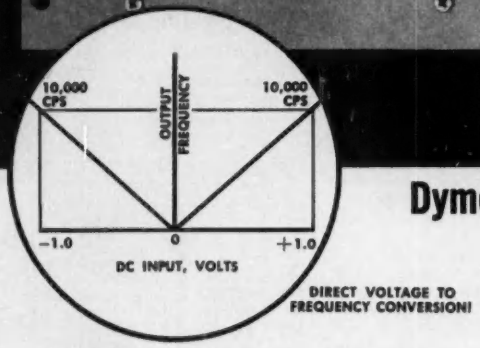
NOW!

Use your electronic counter as an accurate digital voltmeter and integrator





DIRECT VOLTAGE TO FREQUENCY CONVERSION!

New

Dymec Voltage-to-Frequency Converter

Multiple input ranges, either polarity

Inherent noise-averaging characteristics

Output frequency 0 cps to 10 KC

1 megohm input impedance

0.1% accuracy

Easily used in remote and automatic programming applications

Here is a compact new instrument which embodies a truly unique approach to the analog-to-digital conversion problem. You can now make accurate, dependable voltage measurements with your standard electronic counter, viewing results in direct, digital form on the counter. The instrument and its associated counter also serve as an electronic integrator permitting direct measurement of the time integral of dc voltages and other variables without time-consuming manual data reduction and analysis. These characteristics make the DY-2210 an ideal basic component for data handling systems.

The new DY-2210 converter generates output pulses at a rate proportional to the dc signal voltage. This renders the instrument virtually insensitive to noise, and makes possible average measurements of pulsating voltages and currents. The voltage measuring interval is determined by the associated counter. Either positive or negative voltages can be measured without reversing leads or switching.

Immediate shipment from stock. For complete details or demonstration see your Dymec representative or write direct for information.

CONDENSED SPECIFICATIONS

Input Voltage Ranges: 0 to 1, 10, 100 and 1,000 v dc; manual selection.
Input Impedance: 1 megohm, 200 μμf shunt, all ranges.
Input Polarity: Positive or negative. Polarity automatically sensed.
Output Frequency: Zero to 10,000 cps.
Accuracy: Within 0.1% full scale.
Calibration: Against internal mercury cell or external voltage standard.
Power: 115 v ± 10%, 60 cps, 35 watts.
Dimensions: Cabinet model, 7¼" wide, 11¼" high, 10¼" deep. Rack mount model, 19" wide, 3½" high, 10¾" deep.
Price: $650.00 (Rack) $660.00 (Cabinet).
Data subject to change without notice. Prices f.o.b. factory.

See us at I.R.E. Booth 3019-3020.

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DYMEC INC.
(formerly Dynac, Inc.)
5168C Page Mill Road • Palo Alto, Calif., U.S.A.
DAvenport 6-1755
Field representatives in all principal areas

NEW PRODUCTS

SYSTEM ANALYZER covers 0.01 to 110 cps.

Photo at the right shows a new control system analyzer designed to facilitate investigation of feedback control systems over the frequency range of 0.01 to 110 cps. Its manufacturer has drawn heavily on the experience of control systems designers and has produced a unit that

- eliminates the problem of continual meter movement
- reduces distortion caused by nonlinear elements
- rejects completely any dc bias

To overcome these last two difficulties, the instrument evaluates the Fourier expression for the "in-phase" and "quadrature" components of the fundamental in the waveform under test. These are expressed as follows:

$$a_1 = \omega/\pi \int_0^T \sin\ \omega t\, F(t)\, dt$$

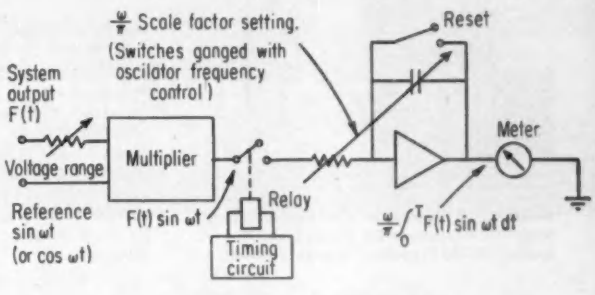
$$\text{and } b_1 = \omega/\pi \int_0^T \cos\ \omega t\, F(t)\, dt$$

where $F(t)$ represents the waveform at the output of the system under test. To provide, for example, the "in-phase" component, the instrument multiplies this output waveform by the reference voltage, sin ωt, then integrates this product over a time T equal to the period of one cycle. This integral is then multiplied by the scaling factor ω/π. As shown in the block diagram, integration time is controlled by a relay. The timing circuit closes the relay for one complete cycle. When the relay opens, the integrator maintains a steady meter reading.

The scaling factor, ω/π, depends on the frequency under investigation and is set by switches controlling the integrator time constant. Housing a decade oscillator and the phase-sensitive voltmeter in the same cabinet eliminates the need for two sets of frequency controls.

Oscillator section offers a direct output of 20 volts peak at 15 ma, maximum, and an attenuator output of from 0 to 20 volts peak by means of precision 10-turn pots. A phase-sensitive voltmeter section covers 0 to 150 volts in eight ranges on a center-zero meter.—Short Brothers & Harland, Ltd., London, England.

Circle No. 200 on reply card



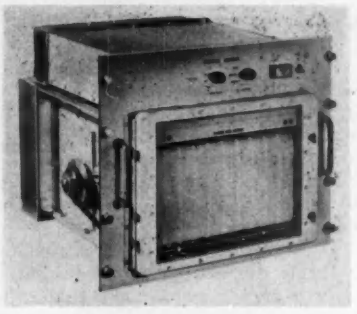
CARD READER eliminates errors.

Designed for use with Richardson's Select-O-Weight proportioning equipment, this compact punched-card reader requires no special skills of the operator, prevents material waste through human error, and assures product uniformity. Other advantages of a punched-card input are the protection of secret formulas and the ability to use the same cards for cost calculations and billing purposes.

Unit can be supplied with a maximum of 960 pins to make contact through a standard IBM card. Pins are rated at 100 ma, nonswitching; position limit switches will handle 15 amp at 125, 250, or 460 vac.—Richardson Scale Co., Clifton, N. J.

Circle No. 201 on reply card

DATA HANDLING & DISPLAY



MONITORS 100 OPERATIONS

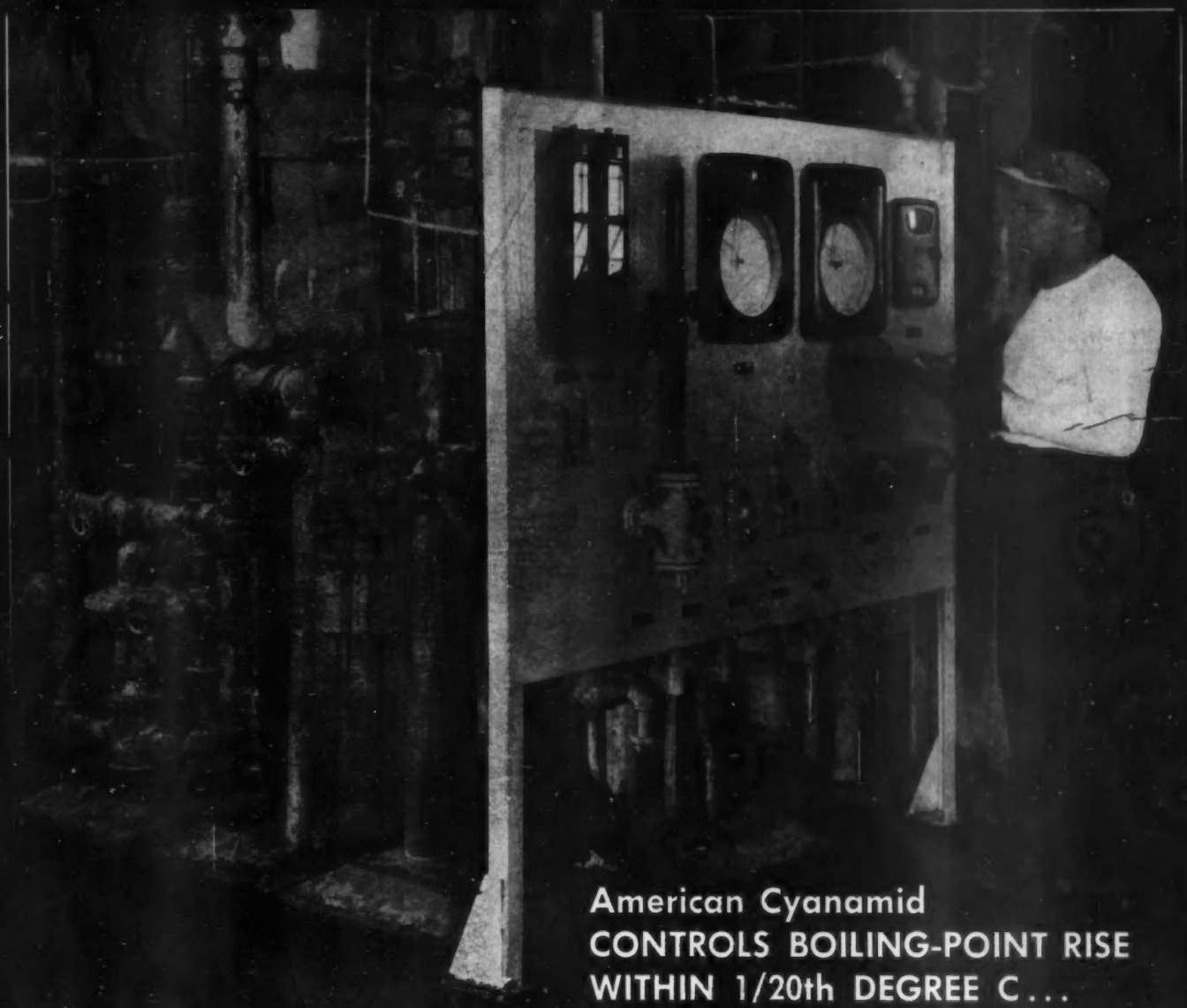
Designed for military and rigorous industrial applications, this rugged instrument will monitor and record up to 100 separate and distinct operations in a 12-in. strip chart. Features include electric writing for unattended operation, a rapid response of up to 500 signal changes per sec, instantaneous selection of eight chart speeds, and a 500-ft chart capacity. Unit draws 250 watts at 105-125 volts, 60 cps.—Brush Instruments, Cleveland, Ohio.

Circle No. 202 on reply card

LOW-LEVEL MULTICODER

Well-suited for handling thermocouple and strain gage data in missile flight tests, the ML Series PDM Multicoder is available in all standard IRIG sampling rates and channel configurations. Maximum input sensitivity is from 0 to 10 mv for full scale, with adjustable gain providing any range up to 100 mv full scale. Unit consists of an electromechanical commutator, dc amplifier, PAM to PDM converter, and power supply.—General Devices, Inc., Princeton, N. J.

Circle No. 203 on reply card



American Cyanamid
CONTROLS BOILING-POINT RISE
WITHIN 1/20th DEGREE C...

by unique narrow-span DYNALOG* Electronic Controller

Temperature difference control within ½ of 0.1°C — that's what American Cyanamid demands for process evaporators at their Organic Chemicals Plant in Bound Brook, New Jersey. Boiling-point rise must be held at 108.5°C, since even slight variations affect product quality.

A Foxboro Dynalog Recorder-Controller, with full-scale span of only 5°C, provides the close control American Cyanamid requires. Control is held continuously within 1/20th of a degree of set point — with chart records for proof.

Cyanamid's Narrow Span Controller was installed in 1955. It's been running continuously ever since, virtually unattended. The only servicing or maintenance required on the Dynalog has been re-inking and chart changing.

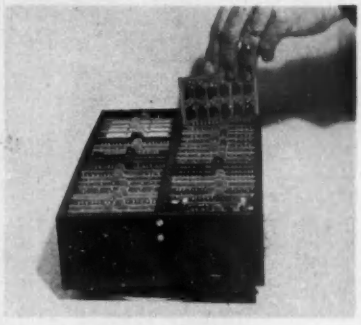
Get the complete story on the exclusive Dynalog Controller, with full-scale spans as narrow as 5°F — the narrowest span available to industry today! Write for Bulletin 20-10. The Foxboro Company, 363 Norfolk St., Foxboro, Mass. *Reg. U. S. Pat. Off.

FOXBORO
REG. U.S. PAT. OFF.

DYNALOG ELECTRONIC INSTRUMENTS

CIRCLE 96 ON READER-SERVICE CARD

NEW PRODUCTS



AIRBORNE CONVERTER

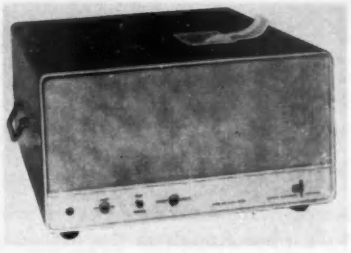
This rear view of a new multichannel analog-to-digital converter illustrates its modular construction and compact printed circuit design. Called the Model CG-591, the unit weighs only 7 lb and uses the PCM method of operation to provide accuracies within 0.2 percent.

Characteristics:

Input impedance: 1 megohm for frequencies to 40 cps; nominally 10 megohms at dc.
Number of inputs: normally 12
Input range: plus or minus 5 vdc
Sampling rate: 120 per sec
Output signals: dc voltage pulses or steps of 3 minimum shifts per channel

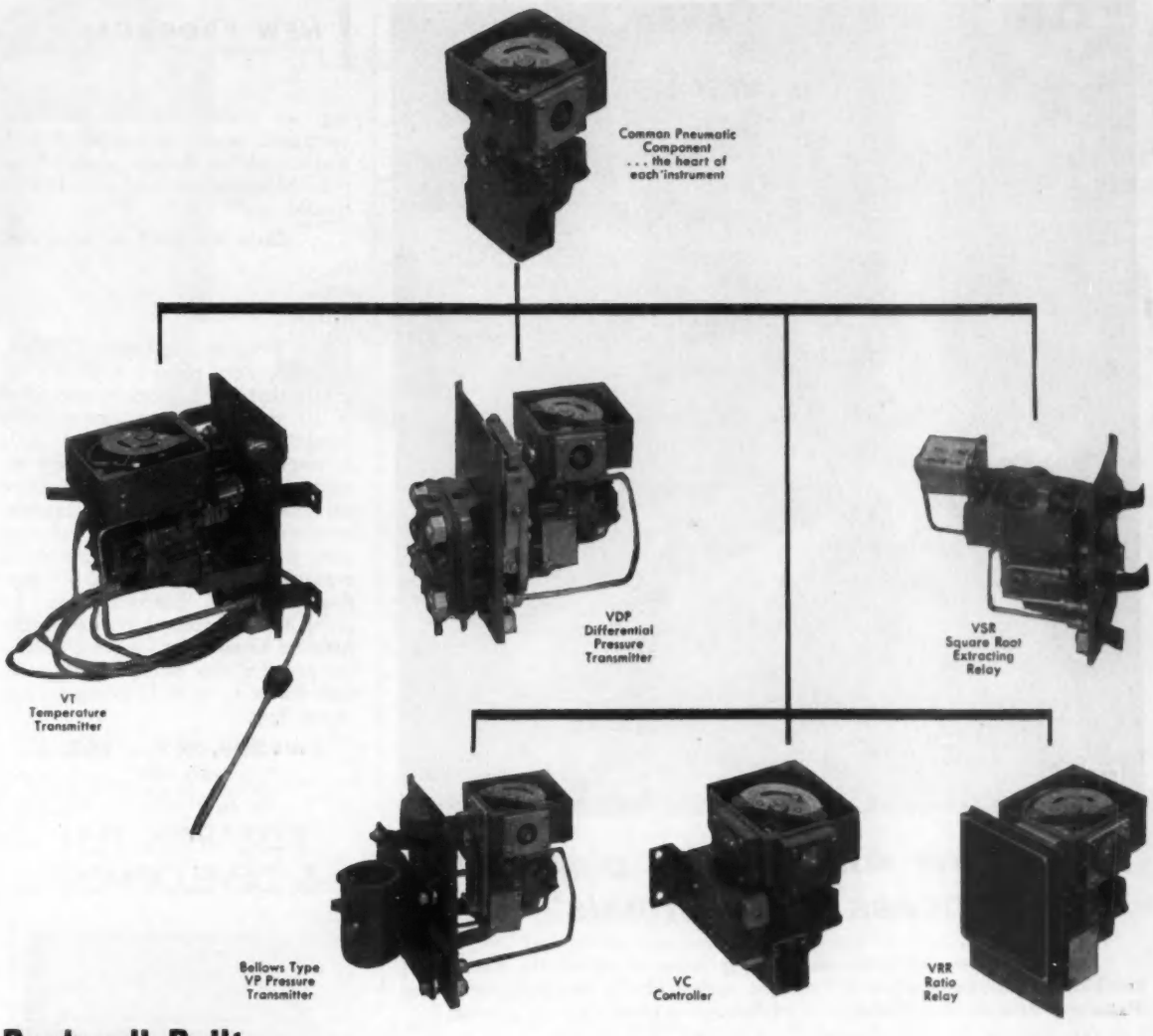
—Gulton Industries, Inc., Metuchen, N. J.

Circle No. **204** on reply card



HIGH-SPEED PRINTER

This Model 400C digital printer was designed to handle the output of high-speed counting, timing, frequency-measuring, and data-handling equipment. Standard design features include parallel entry, unitized construction, and the elimination of stepping switches. Among its optional features are: a 10-line output from each digit for operating a card or tape punch or electric typewriter; an analog output for driving graphic recorders; an inline readout for visual monitor-



Rockwell-Built

Republic Vector Series Instruments

serve any process, cut costs too!

You can save substantial money when your control systems are based on Republic's Null-Balance Vector instruments. Each has as its "heart" an identical pneumatic component, with obvious advantages. Among these are interchange of parts, even among instruments performing entirely different functions. Besides involving a minimum spare parts inventory, this feature greatly simplifies personnel training.

Components shown demonstrate the depth of the Republic line. Differential pressure transmitters with 20-to-1 range adjustment . . . temperature transmitters with 10-to-1 range adjustment . . . pressure transmitters of ±.5% accuracy. We have ratio, totalizing, multiplying, squaring and square root extracting relays. Our all-purpose controllers feature proportional band adjustment of 2% to 500% and reset adjustment from 0.1 to 50 repeats per minute.

The Republic Engineer in your area will be glad to work with you on any control or measurement problem. Sales offices in principal cities throughout the United States and Canada. Call or write—with no obligation, of course.

REPUBLIC FLOW METERS CO.

Subsidiary of ROCKWELL MANUFACTURING COMPANY
2240 DIVERSEY PARKWAY CHICAGO 47, ILLINOIS
In Canada: Republic Flow Meters Canada, Ltd.—Toronto
Manufacturers of electronic and pneumatic instrument and control systems for utility, process and industrial applications.

CIRCLE 98 ON READER-SERVICE CARD

ing; an accumulator for totalizing operations; and a transistorized drive that accepts low voltage inputs.—Computer-Measurement Corp., North Hollywood, Calif.

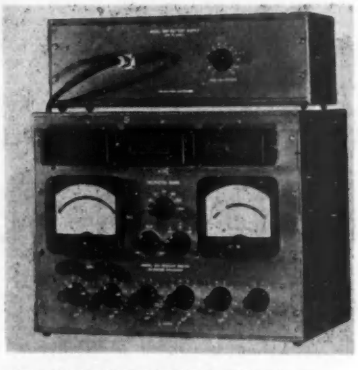
Circle No. 205 on reply card

PLUS. . . .

(206) **Houston Instrument Corp.**, Houston, Tex., offers a $595 **X-Y recorder** that has a standard sensitivity of 10 mv per in. and uses ordinary 8½-by-11-in. graph paper. . . . (207) A magnetic-tape continuous-loop **recorder/reproducer** for the repetitive study of highly transient data, random occurrences, and time-delay applications requiring up to 14 channels, is available from **Consolidated Electrodynamics Corp.**, Pasadena, Calif. . . . (208) The Computer Div. of **Bendix Aviation Corp.**, Los Angeles, Calif., has added a new photoelectric **paper tape reader** to its G-15 computer accessory line.

Circle 206, 207, or 208 on reply card

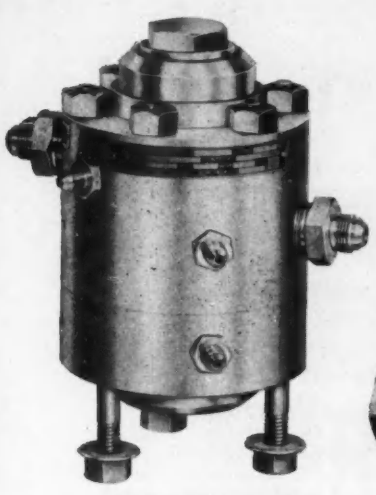
RESEARCH, TEST & DEVELOPMENT



HIGH-RESISTANCE BRIDGE

This new laboratory standard resistance bridge calibrates high megohm resistors to close tolerances, over the range of 1,000 ohms to 110 million megohms. Completely battery operated, and mounted in a solid oak case, the bridge is accurate to within 0.2 percent on values up to 10^{10} ohms. Test potential can be varied up to 1,000 volts to permit accurate voltage coefficient analysis.—Mid-Eastern Electronics, Inc., Springfield, N. J.

Circle No. 209 on reply card



GD60 AND 80 SERIES

GD100 SERIES

GD700 SERIES

Control gases safely, accurately

to 15,000 psi and 200,000 scfh with VICTOR REGULATORS

You get precise regulation of high pressure gases with large flow rates, because Victor employs gas pressure to control the regulating diaphragm. The result is accurate delivery from 5 to 15,000 psi with inlet pressures to 15,000 psi . . . plus ability to obtain flows in excess of 200,000 scfh at maximum inlet and outlet pressures. Chart below shows operating range of standard models.

MODEL NO.	MAX. INLET PSI	MAX. OUTLET PSI	FEATURES	MAX. FLOW SCFH
GD10	3,600	500	Single adjustment regulator control	15,000
GD30	2,500	2,500	Load & bleed valve control	25,000
GD31	3,600	3,600	Load & bleed valve control	36,000
GD61C	2,500	2,500	Load & bleed valve control	10,000
GD62C	3,600	3,600	Load & bleed valve control	12,000
GD65	6,000	6,000	Load & bleed valve control	15,000
GD65C	7,000	7,000	Load & bleed valve control	15,000
GD80A	5,000	5,000	Load & bleed valve control	30,000
GD81A	10,000	10,000	Load & bleed valve control	50,000
GD86R	10,000	10,000	For remote control only	75,000
GD100R	6,000	6,000	For remote control only	240,000
GD100	6,000	6,000	Load & bleed valve control	240,000
GD700	7,000	7,000	Single adjustment regulator control; self relieving	15,000
SR10	3,600	1,000	Small, spring loaded regulator	200
LR20B	7,000	7,000	Spring loaded regulator; self relieving	120

Operating temperature range: −67°F. to +250°F.

. . Yours for the asking
Take advantage of Victor's long experience with high pressure gas regulation to help solve your special problems involving flow rates, delivery pressures, corrosive fluids and temperature compensation. Write, wire or phone us today. No obligation.

All models listed are field proved. Most are designed for panel mounting or remote control. They regulate all non-corrosive gases, including oxygen. Stainless steel models available for corrosive gases and pressures above 10,000 psi. For complete specifications, write for Victor High Pressure Regulator sheets.

VICTOR for regulators

VICTOR EQUIPMENT COMPANY 59

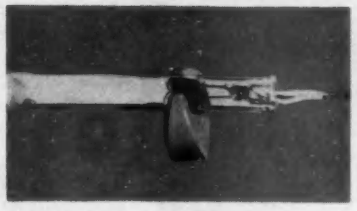
Mfrs. of High Pressure and Large Volume Gas Regulators; welding & cutting equipment; hardfacing rods; blasting nozzles; cobalt & tungsten castings; straight-line and shape cutting machines.

844 Folsom St., San Francisco 7 • 3821 Santa Fe Avenue, Los Angeles 58 • 1145 E. 76th St., Chicago 19

J. C. Menzies & Co., Wholly-Owned Subsidiary

CIRCLE 100 ON READER-SERVICE CARD

NEW PRODUCTS



HIGH-VACUUM GAGE

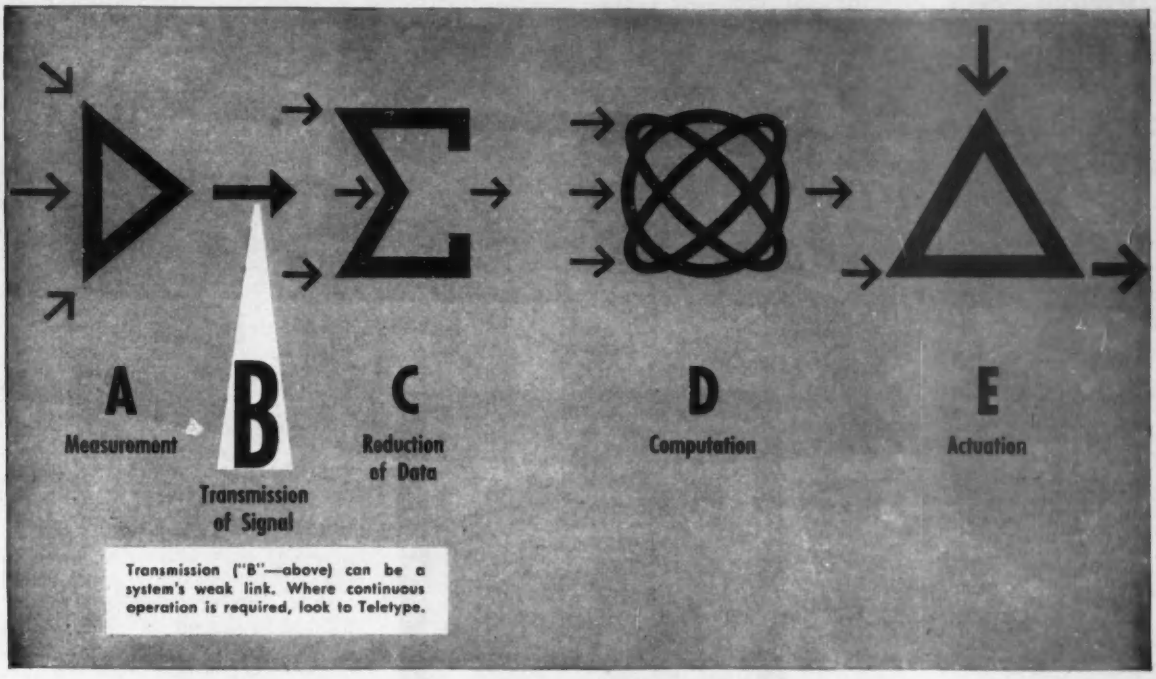
A new ionization-type vacuum gage, the Model 100-A, operates over the range of 10^{-4} to 10^{-7} and uses this cold-cathode gage tube, an open-ended Pyrex tube with two electrodes, as a sensing device. A high potential between the U-shaped anode and the circular cold cathode provides an electron stream, which is aligned by a magnetic field. Gas particles present in the vacuum ionize on collision with these electrons. Collection of the ions at the cathode generates a current that is directly proportional to the amount of gas present. Unit draws 3½ amp (including protection load) at 115 volts, 60 cps.–Miller Laboratories, Latham, N. Y.

Circle No. **210** on reply card

WIDE FREQUENCY RANGE

The Model 1715 square-wave generator is well-suited for either laboratory or production testing of triggering, coding, or gating networks and circuits. It has a rise time of 0.02 microsec and covers a frequency of from 1 cycle to 1 megacycle in six decade bands. A main frequency dial, graduated from 1 to 10, permits infinite variation. Mechanical design provides for easy access and excellent ventilation. Complete unit sells for $265.–The Hickok Electric Instrument Co., Cleveland, O.

Circle No. **211** on reply card



Teletype — Symbol for continuous operation

Teletype equipment was born to demanding applications; railroad stations located too far for servicing, 24-hour newspaper and telegraph jobs, the stock exchange where a breakdown could cost a fortune . . . and rough hitches with the armed forces.

The Model 28 printer incorporates Teletype dependability with a host of new features for communication and data processing applications.

Attention Free. The Teletype Model 28 printer is designed for minimum maintenance. Lubrication interval at 100 word per minute speed is 1,500 hours—at 60 word per minute it's 3,000 hours! Motors were specially designed for the Model 28, to give long, attention-free operation. The printer is not affected by tilting or severe vibration, works reliably even in mobile applications. Other attention-free features:

1 New type box. Characters are contained in a compact, lightweight assembly. Each character is on a separate pallet—type alignment is built in, overscoring and underscoring eliminated. The type box can be quickly removed, without tools, for cleaning or changes in type arrangement.

2 Tests at 100 WPM in continuous operation show 9,000,000 words printed, without servicing. Paper guides and pressure rollers are designed to provide straight-line paper feed, insuring accurate, continuous, paper alignment.

3 All steel clutches give firm, uniform, and accurate engagement, cycle after cycle . . . operate with exceptional stability . . . deliver high torque capable of handling positive and negative loads. Internal expansion principle in clutch design minimizes wear. Lubrication interval is reduced to once or twice a year.

New—Versatile, too. The Teletype Model 28 printer is a new instrument . . . engineered to "cruise" at 100 WPM. It is attractively styled and quiet in operation.

Exclusive with the Teletype 28 Printer is the versatile Stunt Box, which is actually a "robot brain." Responding to keyboard or line signals, it may be used for internal control of extra functions in the Teletype printer and for remote control of associated or other electronic or mechanical equipment.

For more information about this Teletype Model 28 printer—write to Teletype Corporation, Dept. 22C, 4100 Fullerton Ave., Chicago 39, Illinois.

TELETYPE®
CORPORATION
SUBSIDIARY OF *Western Electric Company* INC.

NEW PRODUCTS

ELECTRONIC TACHOMETER

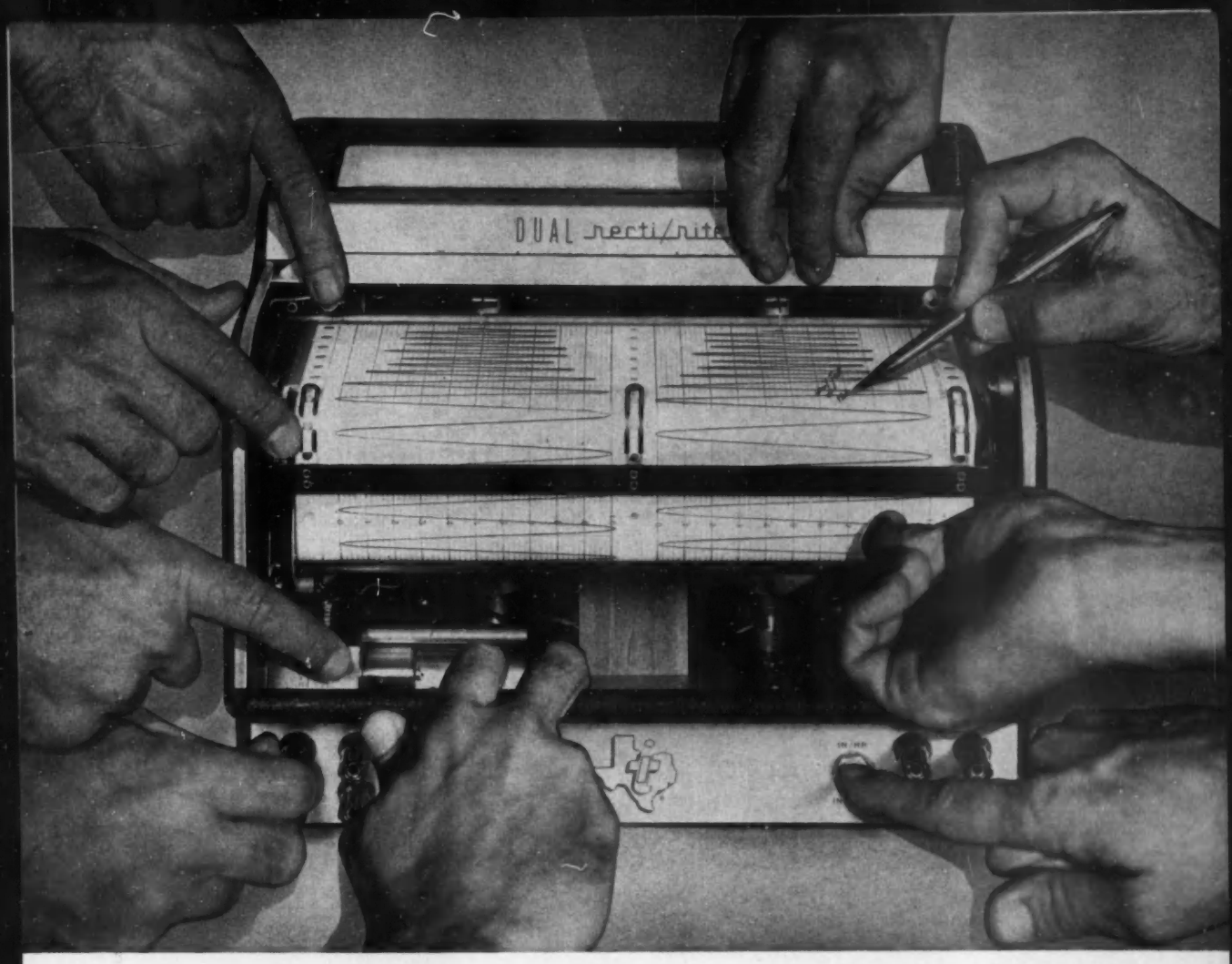
A new portable tachometer, using in-line Nixie tubes for a direct digital readout, has been developed to simplify measurement of shaft speeds from ½ rpm to 50,000 rpm. Unit reads speeds to within 1 rpm in 1/16th sec or to within 10 rpm in 1/100th at all speeds. Continuous indication eliminates need for dial tachometers. —Dynapar Corp., Skokie, Ill.

Circle No. 212 on reply card

CHECKS THERMOCOUPLES

This new test stand, the Model TC-2 Thermocouple Calibrator, features a precision constant-temperature reference junction in place of the stainless steel ice bath and test tubes formerly used for cold junction compensation. All instrumentation is rack-mounted. Equipment includes potentiometer, standard cell, null indicator, wet-cell storage battery, 24-point rotary switch, furnace control instrumentation, and a Bureau of Standards calibrated platinum-platinum rhodium thermocouple. Unit will handle 24 couples at one time. —Arcweld Mfg. Co., Grove City, Pa.

Circle No. 213 on reply card



recti/riter® recorders make YOUR work easier with up-front control of all operations

Work-saving "recti/riter" recorders place all routine adjustments and controls at your fingertips for maximum operator convenience.

With the greatest ease and speed, you can . . .

1. Raise the transparent, dust-proof door . . .
2. Make notes on "writing desk" area . . .
3. Remove, tear off, or change chart paper . . .
4. Flip the power switch . . .
5. Adjust zero position of writing pens . . .
6. Make connections to front terminals . . .
7. Select any of 10 chart speeds . . .
8. Advance chart paper as desired manually . . .
9. Check visible ink supply level or refill.

And, of course, removal of the dust cover makes every working part completely accessible — and removable — without further disassembly.

Add to these convenient features true rectilinearity, side-by-side time-correlated traces readable at a glance, fast rise time, galvanometer dependability and ±1% full-scale accuracy. Yes, and remember —*only* "recti/riter" systems (recorders and matching accessories) provide these wide ranges for recording electrical parameters:

10 millivolts to 1000 volts
500 microamperes to 1000 amperes
Monitor standard frequencies — 40, 60, 400 cps

Just a word from you will bring complete information on the "recti/riter" line. Inquire today!

TEXAS INSTRUMENTS
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OTHER TI/IID PRODUCTS

- Complete Geophysical Instrumentation
- DATA-GAGE Measurement and Control Systems
- Automatic Test Equipment

CIRCLE 104 ON READER-SERVICE CARD

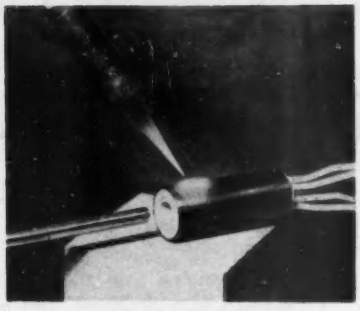
NEW PRODUCTS

PLUS . . .

(214) **Consolidated Electrodynamics Corp.**, Pasadena, Calif., has announced a new **high-temperature chromatograph** capable of separating and analyzing substances with boiling points up to 600 deg C. . . . (215) The Model 107A Feedback **Electrostatic Voltmeter** by **Monroe Electronic Laboratories, Inc.**, Middleport, N. Y., permits drift-free measurement of the voltage on an electrostatically charged surface. . . . (216) A low-cost, rack-mounted **viewing oscilloscope,** with horizontal and vertical sensitivity of 20 mv per in., is now in production at **American Electronic Laboratories, Inc.**, Philadelphia, Pa. . . . (217) **The Kennedy Co.**, Pasadena, Calif., offers a **pulse-waveform generator** that produces long calibrated pulses suitable for testing electromechanical devices, computers, and input-output equipment.

Circle No. 214, 215, 216, or 217 on reply card

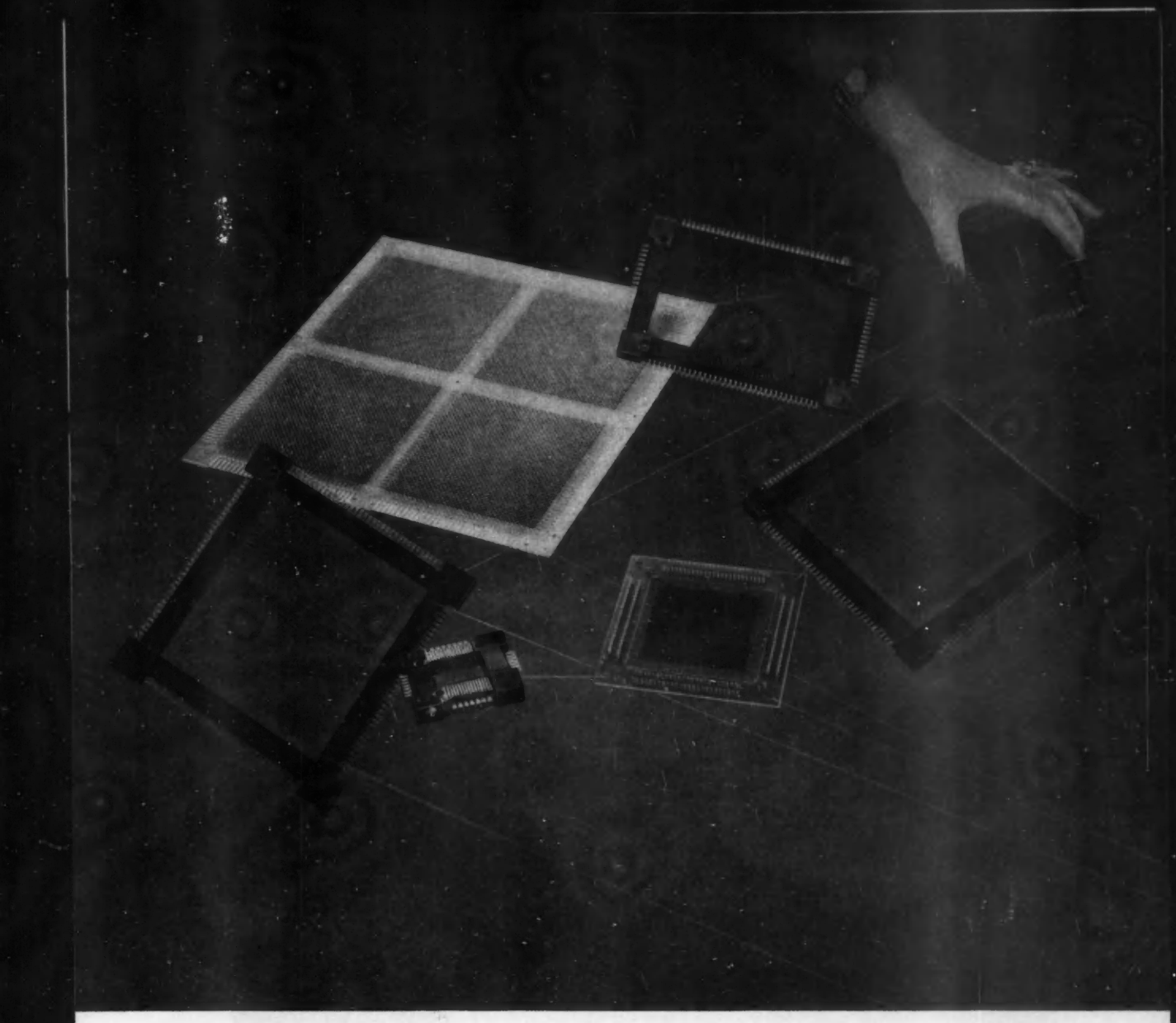
PRIMARY ELEMENTS & TRANSDUCERS



BREAK HI-TEMP BARRIER

High-temperature differential transformers, Types 6208-HHK and 6206-HHK, are now available for prototype and model evaluation. Because their coils are wound on special ceramic bobbins, these units will operate continuously at 1,000 deg F and withstand 2,000 deg F for periods up to 5 min. The 6208 model is for linear displacements up to 0.150 in., either side of center; the 6206 handles displacements up to plus or minus 0.500 in.—Automatic Timing & Controls, Inc., King of Prussia, Pa.

Circle No. 218 on reply card



Find the missing memory plane

The seven memory planes above each solved some special memory problem. There is one plane missing. It's the one which will solve your problem. You'll find the plane at General Ceramics which offers a complete memory plane service, backed by broad experience in the design, engineering and mass production of planes, frames and cores.

DESIGN SERVICE– An experienced design engineering staff stands ready to analyze your memory plane requirement, recommend and develop the plane that will meet your application in the most efficient and least expensive manner.

VISIT BOOTHS 2221-2223 I.R.E. SHOW!

MANUFACTURE– Skilled factory personnel, utilizing the most advanced equipment and techniques and continually working in all phases of memory plane development and manufacture will produce the plane. General Ceramics has developed and wired memory planes containing from 64 to 16,384 cores each. (Core sizes range from 50 mil OD to 80 mil OD.)

QUALITY CONTROL– An expanded testing department with fully automatic and semi-automatic testing equipment, developed at General Ceramics, assures you complete quality control and the highest standards of manufacture.

STANDARD LINE– Perhaps some of General Ceramics' line of standard memory frames will meet your requirements. Write for literature on General Ceramics standard planes. Address inquiries to General Ceramics Corporation, Keasbey, N. J.–Dept. CE.

GENERAL CERAMICS

ORIGINATOR OF THE SQUARE LOOP FERRITE

Manufacturers of FERRAMIC CORES, MAGNETIC MEMORY CORES, MEMORY PLANES, MICROWAVE FERRITES, SOLDERSEAL TERMINALS, HIGH TEMPERATURE SEALS, STEATITE, ALUMINA and CHEMICAL STONEWARE

CIRCLE 106 ON READER-SERVICE CARD

NEW PRODUCTS

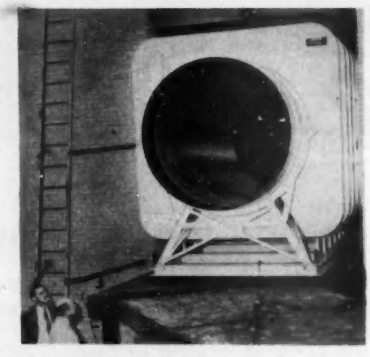
VIBRATION PICKUP

Manufacturer claims that this new Type II vibration pickup, called the "Vibramite", is the only eddy current damped unit available today with a flat response curve over its full operating range. Tests indicate that accelerations up to 50 g continuous or 100 g intermittent will not damage the unit.

Characteristics:

Sensitivity: 96.3 mv per in. per sec
Response: flat within 5 percent from 40 to 2,000 cps
Temperature: minus 85 to 500 deg F
Size: 1.42 in. sq by 1 in.
Weight: 2.75 oz.
—MB Mfg. Co., New Haven, Conn.

Circle No. 219 on reply card



WORLD'S LARGEST

Photo above shows an end view of the world's largest magnetic flowmeter being readied for transportation. Slated for installation in a new Pittsburgh sewage plant, the meter has a bore of 72 in. and a length of 16 ft. In service, it will handle up to 350 million gpd of raw sewage influent with no added pressure drop. Meter tube consists of layers of fiberglass cloth bonded by polyester resin. One end terminates in a Dresser coupling

to facilitate connection to a 10-ft sewage tunnel; the other end is bonded to a flange.—The Foxboro Co., Foxboro, Mass.

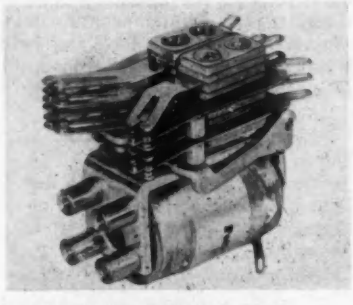
Circle No. 220 on reply card

PLUS. . . .

(221) The X-ray Dept., **General Electric Co.**, Milwaukee, Wis., has developed a new X-ray gage for measuring low-density materials such as paper and fabrics. . . . (222) The Model 0358-1 **liquid level gage**, recently introduced by **Magnetic Instruments Co., Inc.**, Thornwood, N. Y., features measuring accuracies within $\frac{1}{10}$ in. over a 10-ft range. . . . (223) a small **differential switch** used to sense relative displacement between two shafts is now available from the **Newton Co.**, Manchester, Conn.

Circle 221, 222, or 223 on reply card

CONTROLLERS, SWITCHES & RELAYS



NEW DESIGN ADDS LIFE

A modified version of this company's short-coil telephone-type relay features bifurcated contact arms with as many as 20 arms per relay. Design changes permit higher contact loads and provide a longer, more reliable operating life. Designated the TS Series, these relays operate on as little as 100 mw per movable arm at up to 110 vdc, and will switch up to 4 amp at 115 volts, 60 cycles, resistive.—Potter & Brumfield, Inc., Princeton, Ind.

Circle No. 224 on reply card

ULTRA-HIGH SPEED

A brand new semiconductor switching device currently being used in experimental computer equipment is capable of switching current in about 50 trillionths of a sec or about twice as fast as can be measured on the best avail-

able instruments. Heart of the new switch is a tiny semiconductor alloy junction made by fusing a speck of aluminum to a tiny piece of silicon. A small voltage pulse is used to trigger the current flow.–Sperry Semiconductor Div., Sperry Rand Corp., Norwalk, Conn.

Circle No. **225** on reply card

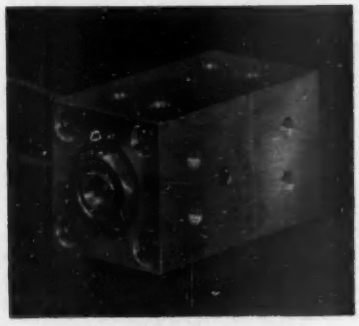
DELAYS FROM 1 TO 300 SEC

This actual-size photo shows one of a new line of subminiature time delay relays designed for high-altitude, high-vibration, and high-temperature applications. Units weigh ¾ oz and have a seated height of 1⅝ in. Plug-in or solder terminals are optional.

Characteristics:

Vibration: 10 g, 5 to 1,000 cps
Shock: up to 50 g
Temperature: minus 65 to 125 deg C
Heater voltages: to 150 volts, ac or dc
Contacts: spst, no or nc
Power drain: 4 watts
–Dialtron Corp., Brooklyn, N. Y.

Circle No. **226** on reply card

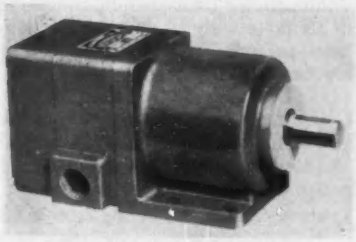


ACCELERATION SENSITIVE

Operating on a unique principle, this new acceleration-sensitive switch is continuously adjustable for sensitivity to both positive and negative accelerations along a single axis. Heart of the unit is a seismic mass located in the

center of a dished element. Outer edge of the dished element is held by the switch housing. Force, a product of the fixed mass and its acceleration, causes this element to assume either of two stable positions. Switch contacts have a current carrying capacity of 2 amp max. Sensitivity of the unit shown on page 160 can be adjusted over a 30-g range, plus or minus.—Eastern Technical Associates, Inc., Concord, Mass.

Circle No. 227 on reply card



RUGGED ENCLOSURE

The Bulletin 2210 Centrifugal Switch, housed in a tough molded resin enclosure, offers an overall adjustable speed range of from 70 to 5,000 rpm and may be adjusted while running. Two separate sets of contacts permit a single switch to control two different operations. Unit measures 7¾ in. long by 3⅞ in. high and 3¾ in. wide.—Euclid Electric & Mfg. Co., Madison, O.

Circle No. 228 on reply card

SKELETON SWITCH

Designed for use by original equipment manufacturers or in industrial installations where controls are housed in a common cabinet, the Model 404 unhoused, dual-setting pressure switches operate on either gas or liquid pressure. Insensitive to vibration, they can be mounted in any position. Accuracy, repeatability, and other characteristics are comparable to housed models released earlier by this company.

Characteristics:

Proof pressures: 30 in. Hg vacuum to 150 psi

Switching elements: spdt, with automatic reset

Pressure settings: two, covering any range between 30 in Hg vacuum and 100 psi

—Pressure Switch Div., Barksdale Valves, Los Angeles, Calif.

Circle No. 229 on reply card

PLUS. . . .

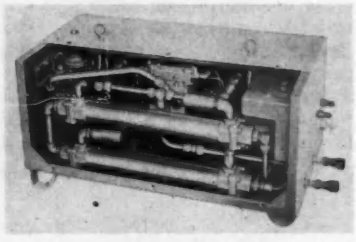
(230) **United Electric Controls Co.**, Watertown, Mass., has announced the

NEW PRODUCTS

addition of five new models to its J40 line of **lightweight pressure switches,** extending the overall range of the line to 0 to 350 psi. . . . (231) the PA-070 **spring return switch,** developed by **Centralab Div of Globe-Union Inc.,** Milwaukee, Wis., features an improved type of construction that eliminates the use of costly coil springs. . . . (232) a new solenoid-operated unidirectional **rotary switch,** consisting of six poles with 24 nonshorting positions per pole, is available from **The Daven Co.,** Livingston, N. J. . . . (233) **Barksdale Valves,** Los Angeles, Calif., recently introduced a **pressure switch** for sensing differentials from 5 to 140 psi in oil systems with working pressures from 50 to 6,000 psi.

Circle No. 230, 231, 232, or 233 on reply card

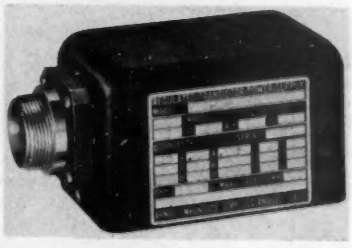
POWER SUPPLIES



HIGH-CAPACITY

Designed for all types of hydraulic components, this compact power unit, called the "Pack-Horse", provides flow up to 3.5 gpm at pressures to 3,000 psi. Well-suited for use as a standby power source, the unit contains all necessary safety and control features. Its integral heat exchanger insures cool operation and connects to any plant's compressed air line.—M. B. Sturgis, Inc., St. Louis, Mo.

Circle No. 234 on reply card



POWER INVERTER

This compact transistorized power in-

verter helps to get maximum performance from ac gyros and motors by producing an ac sine-wave output from a battery line source. Its sinusoidal output avoids the heat-producing harmonics of square-wave operation. Operating the transistors as saturated switching elements maintains efficiency.

Characteristics:

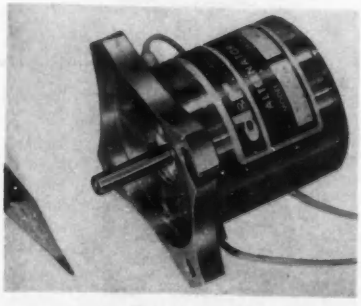
Input voltage: 24, 26, or 28 vdc
Output voltage: 26 and 115 vac
Output frequency: 400 cps, standard
Output power: 40 va
Weight: 32 oz, complete
—Arnold Magnetics Corp., Los Angeles, Calif.

Circle No. 235 on reply card

NEW BUTTON CELLS

Slightly thicker than a five-cent piece and weighing only ¼ oz, these new rechargeable nickel-cadmium cells were designed for miniature and subminiature electronic applications. Ruggedly built, they exhibit no gasing during recharge, require no filling or electrolyte, and can be discharged at currents up to 10 times their normal capacity. At proper charging rates, they can be recharged indefinitely without fear of damage. — Gulton Industries. Inc., Metuchen, N. J.

Circle No. 236 on reply card



SHAFT SPEEDS TO 60,000 RPM

The Model D-1309, a small, lightweight generator suitable for use in missile power supplies, develops 100 watts of power at 6,000 cps with shaft speeds to 60,000 rpm. Design fea-

NEW PRODUCTS

tures low internal impedance, low starting torque, low inertia, and short circuit protection. Unit weighs 6.5 oz and measures 1.5 in. in diameter by 1.67 in. long.—D&R, Ltd., Santa Barbara, Calif.

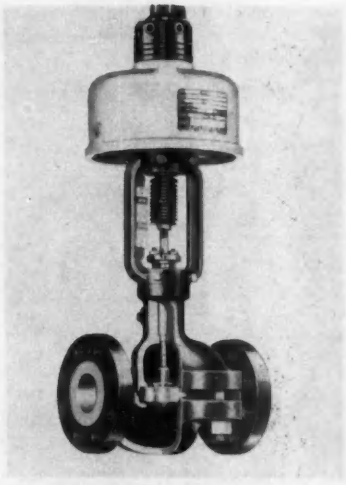
Circle No. **237** on reply card

PLUS. . . .

(238) A brand new all-transistor 0 to **1 amp power supply,** by **Lambda Electronics Corp.,** College Point, N. Y., is available with or without meters and carries a full five-year guarantee. . . . (239) **Mid-Eastern Electronics, Inc.,** Springfield, N. J., offers a **0-to-36-vdc transistorized supply** with line and load variations limited to less than 0.1 percent. . . . (240) **A 28-vdc filament supply,** with metal base and octal plug base, was recently introduced by **C. J. Applegate & Co.,** Boulder, Colo. . . . (241) **Perkin Engineering Corp.,** El Segundo, Calif., has developed a dual-output, **12-kw dc power supply** for industrial applications and research programs.

Circle **238, 239, 240,** or **241** on reply card

ACTUATORS & FINAL CONTROL ELEMENTS



SPLIT-BODY VALVES

Built to conform to accepted ISA standards for face-to-face dimensions, this new line of split-body control

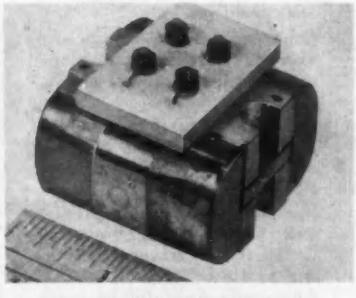
valves is well-suited for high-temperature, high-pressure applications. Unitized construction of all major components makes it possible to develop 432 different valve combinations from a single split body. According to the manufacturer, these valves offer the highest capacities available in this type of construction.–Kieley & Mueller, Inc., Middletown, N. Y.

Circle No. 242 on reply card

FOR AIR TO 1,500 PSI

Pictured is the Model 610 four-way pneumatic servovalve, counterpart to the company's Model 410 hydraulic unit announced earlier (CtE, Dec. '58, p. 93). Like the hydraulic unit, the Model 610 will also pass 200 micron particles in both first and second stages, and cannot become unbalanced due to gas contamination. Operating air pressures range from 300 to 1,500 psi; temperatures, from minus 65 to 250 deg. F.–Raymond Atchley, Inc., Los Angeles, Calif.

Circle No. 243 on reply card



OPERATES AT 600 DEG F

This new torque motor, Model 103-2, makes it possible to use electrohydraulic or electropneumatic servovalves and similar devices in high-temperature applications without complicated cooling systems or thermal

NEW PRODUCTS

lag provisions in the overall design of the system.

Characteristics

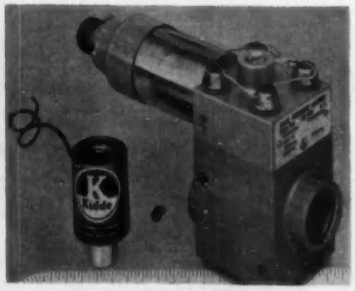
Midposition force: over 8 lb
Stroke: plus or minus 0.008 in.
Power: requires only 4 watts
Dimensions: 1¼ by 1¹⁄₁₆ by 1¾ in.
Weight: 10 oz
—American Measurements & Control, Inc., Waltham, Mass.

Circle No. 244 on reply card

COMBINES FUNCTIONS

Called a "Damperator", this new dual-purpose hydraulic device combines the functions of a flutter damper and rotary actuator. An electronic servo system provides precise rotary motion control with uniform damping rates over a wide temperature range. Designed for installation on rudders and other control surfaces, the unit offers airframe manufacturers important savings in weight and hardware.—Houdaille Industries, Inc., Buffalo, N. Y.

Circle No. 245 on reply card



FOR MISSILE SYSTEMS

Two new pneumatic solenoid valves feature rather unique characteristics.

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2	12	22	32	42	52	62	72	82	92	102	112	122	132	142	152	162	172	182	192
3	13	23	33	43	53	63	73	83	93	103	113	123	133	143	153	163	173	183	193
4	14	24	34	44	54	64	74	84	94	104	114	124	134	144	154	164	174	184	194
5	15	25	35	45	55	65	75	85	95	105	115	125	135	145	155	165	175	185	195
6	16	26	36	46	56	66	76	86	96	106	116	126	136	146	156	166	176	186	196
7	17	27	37	47	57	67	77	87	97	107	117	127	137	147	157	167	177	187	197
8	18	28	38	48	58	68	78	88	98	108	118	128	138	148	158	168	178	188	198
9	19	29	39	49	59	69	79	89	99	109	119	129	139	149	159	169	179	189	199
200	210	220	230	240	250	260	270	280	290	300	310	320	330	340	350	360	370	380	390
201	211	221	231	241	251	261	271	281	291	301	311	321	331	341	351	361	371	381	391
202	212	222	232	242	252	262	272	282	292	302	312	322	332	342	352	362	372	382	392
203	213	223	233	243	253	263	273	283	293	303	313	323	333	343	353	363	373	383	393
204	214	224	234	244	254	264	274	284	294	304	314	324	334	344	354	364	374	384	394
205	215	225	235	245	255	265	275	285	295	305	315	325	335	345	355	365	375	385	395
206	216	226	236	246	256	266	276	286	296	306	316	326	336	346	356	366	376	386	396
207	217	227	237	247	257	267	277	287	297	307	317	327	337	347	357	367	377	387	397
208	218	228	238	248	258	268	278	288	298	308	318	328	338	348	358	368	378	388	398
209	219	229	239	249	259	269	279	289	299	309	319	329	339	349	359	369	379	389	399

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1	11	21	31	41	51	61	71	81	91	101	111	121	131	141	151	161	171	181	191
2	12	22	32	42	52	62	72	82	92	102	112	122	132	142	152	162	172	182	192
3	13	23	33	43	53	63	73	83	93	103	113	123	133	143	153	163	173	183	193
4	14	24	34	44	54	64	74	84	94	104	114	124	134	144	154	164	174	184	194
5	15	25	35	45	55	65	75	85	95	105	115	125	135	145	155	165	175	185	195
6	16	26	36	46	56	66	76	86	96	106	116	126	136	146	156	166	176	186	196
7	17	27	37	47	57	67	77	87	97	107	117	127	137	147	157	167	177	187	197
8	18	28	38	48	58	68	78	88	98	108	118	128	138	148	158	168	178	188	198
9	19	29	39	49	59	69	79	89	99	109	119	129	139	149	159	169	179	189	199
200	210	220	230	240	250	260	270	280	290	300	310	320	330	340	350	360	370	380	390
201	211	221	231	241	251	261	271	281	291	301	311	321	331	341	351	361	371	381	391
202	212	222	232	242	252	262	272	282	292	302	312	322	332	342	352	362	372	382	392
203	213	223	233	243	253	263	273	283	293	303	313	323	333	343	353	363	373	383	393
204	214	224	234	244	254	264	274	284	294	304	314	324	334	344	354	364	374	384	394
205	215	225	235	245	255	265	275	285	295	305	315	325	335	345	355	365	375	385	395
206	216	226	236	246	256	266	276	286	296	306	316	326	336	346	356	366	376	386	396
207	217	227	237	247	257	267	277	287	297	307	317	327	337	347	357	367	377	387	397
208	218	228	238	248	258	268	278	288	298	308	318	328	338	348	358	368	378	388	398
209	219	229	239	249	259	269	279	289	299	309	319	329	339	349	359	369	379	389	399

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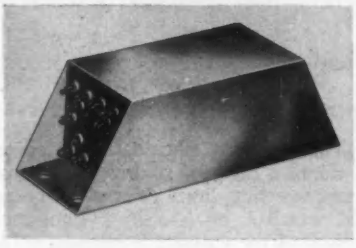
The one on the left is claimed to be the smallest 3,000-psi unit ever made; that on the right, the fastest. The small one operates on 14 to 30 vdc at 0.5 to 1.5 amps with a temperature range of minus 75 to plus 350 deg F, and has a 100-to 10,000-cycle life, depending on operating conditions. The large unit offers an operating pressure range of 80 to 3,250 psi, draws 1.2 amps at 28 vdc, and has a response time of only 0.018 sec. —Walter Kidde & Co., Belleville, N.J.

Circle No. **246** on reply card

COMPONENTS AND ACCESSORIES



SERVO AMPLIFIER

Shown is a brand new magnetic amplifier package developed for aircraft and missile applications. Hermetically sealed, the unit provides a push-pull dc outlet for proportional control of hydraulic transfer valves used in flight-control systems. Its low-emissivity finish permits operation at extremely high radiant energy levels.

Characteristics:

Input range: minus 1 volt to plus 1 volt
Maximum output: 15 ma at 15 volts
Gain: externally adjustable
Overall length: 4½ in.
Weight: 10 oz
—Vickers, Inc., St. Louis, Mo.

Circle No. **247** on reply card

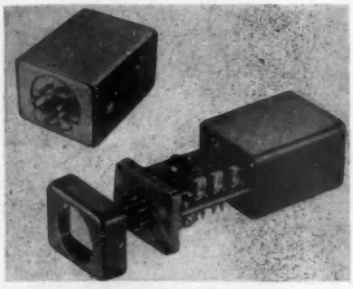
ALL-METAL POT

A new precision 10-turn potentiometer, Model 590, operates over a temperature range of minus 65 to plus 200 deg C, and in resistance ranges from 25 to 120,000 ohms. Only 1 in. in diameter, these units feature all-metal construction of machined aluminum,

with the helical coil directly against the case for maximum heat dissipation. Glass-sealed terminals are flashed with precious metal.

Other characteristics:
Linearity: within 0.3 percent
Vibration: over 20 g from 55 to 2,000 cps
Shock: 30 g
Humidity: 95 percent
—Spectrol Electronics Corp., San Gabriel, Calif.

Circle No. 248 on reply card



PREVENTS ARCING

This modular, plug-in, transistorized circuit is designed to drive all types of self-selecting brush V-scan encoders. Controlled by the least significant digit of the encoder, it provides a 20-volt output of up to 25 ma for the first pair of logic brushes. A transconductance amplifier stage extends encoder life by limiting voltage and current on the encoder's least significant digit, and thus preventing arcing.—Norden Div., United Aircraft Corp., Milford, Conn.

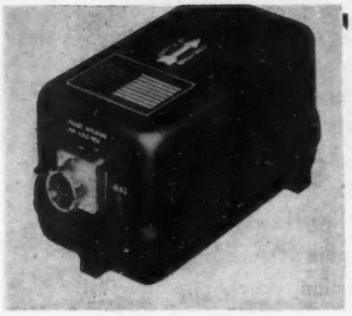
Circle No. 249 on reply card

TINY SHIFT REGISTER

The Model SR-104 miniature shift register, shown above, is a one-core-per-binary-bit unit, with a 5-kc information rate and a signal-to-noise ratio of 10:1. In operation, a 7-ma, 10-μsec input pulse followed by a 300-ma, 8-μsec shift pulse produces a 22-volt,

14-μsec output pulse. Operating temperature range is minus 55 to 125 deg C. Total volume of the unit, encapsulated in an epoxy compound, is only 0.2 cu in.–ESC Corp., Palisades Park, N. J.

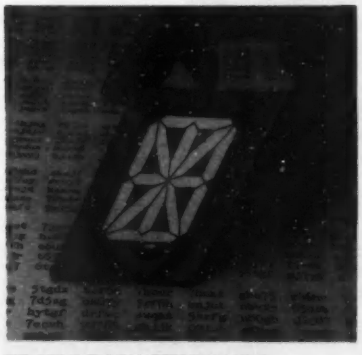
Circle No. 250 on reply card



NEW VERTICAL GYRO

Erection system used in this Series 1080 gyro features two single-axis, gravity-sensing electrolytic-type switches. In the gyro motor, inner bearing race rotation provides maximum bearing life. Flexible design allows the 1080 to be made into a directional gyro or free gyro as well as a vertical gyro. Standard motor operates on 115 volts, 400 cps, three-phase. Unit draws 55 va while starting and 25 va when running. When used as a vertical reference, accuracy is within 0.25 deg for all headings.–Lear, Inc., Grand Rapids, Mich.

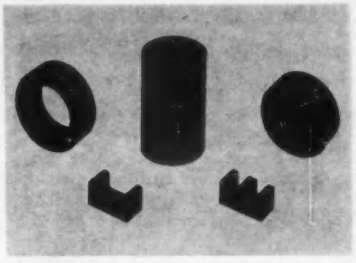
Circle No. 251 on reply card



FLAT READOUT LAMPS

Pictured is a new readout lamp that uses the electroluminiscence phenomenon to display, in a single plane, all the letters of the alphabet, all the numerals, and a number of symbols. Tests indicate that its 2¾-in. characters are clearly visible from 50 ft with ambient lighting of 50 footcandles, and over an extremely wide viewing angle. Called the Alpha lamp, it has 14 segments with which to form the various characters. Also available is a 10-segment Numeric lamp capable of displaying all the numerals, 16 letters of the alphabet, and a few symbols. These Numeric lamps can be had with either 2¾-in. or 1⅜-in. characters. Operating voltages are either 240 or 460, at 60 to 400 cps. On the larger size, lamp and socket combined are less than 1 in. thick, and maximum power consumption is below 0.2 watt. Switching can be handled by relays, rotary switches, diodes, magnetic amplifiers, and other conventional means.–Westinghouse Electric Corp., Pittsburgh, Pa.

Circle No. 252 on reply card



FOR MAGNETIC CORES

A recently developed ferrite material, designated MN-31, offers high initial and maximum permeabilities together with high saturation magnetization and low losses in the frequency range from 10 to 500 kc. High inherent resistivity of the material prevents eddy current losses. Other characteristics include a Curie temperature of over 180 deg C, excellent machinability, and uniform density.–Kearfott Co., Inc., Little Falls, N. J.

Circle No. 253 on reply card

PLUS. . . .

(254) **Kearfott Co., Inc.**, Clifton, N. J. recently placed in production a new 60-cycle transistorized **servoamplifier** for commercial and industrial applications. . . . (255) The Series 308 subminiature **trimming potentiometers**, offered by **Daystrom Pacific**, Los Angeles, Calif., feature complete humidity protection, exceptional environmental stability, and improved resolution. . . . (256) A new line of silicon **power rectifiers**, claimed to have current ratings 25 percent higher than others of similar size and cost, has just been announced by **Vickers, Inc.**, St. Louis, Mo. . . . (257) **Advanced Research Associates, Inc.**, Kensington, Md., now has a silicon composite **pnp transistor** that is thermally compensated for operation at temperatures up to 200 deg C.

Circle No. 254, 255, 256, or 257 on reply card

PARADOXES
FOR COMPUTER SYSTEMS ENGINEERS

Modern military requirements for airborne avionic equipments present to the computer designer the paradox of great system complexity with the constraining factors of extremely high reliability and new orders of miniaturization. Solutions which reflect in the ultimate equipment design must include sophistication in the original approach to the system...in mathematical processes...and in logical design, as well as new hardware concepts.

This paradox presents real challenges to the ingenuity of scientists and engineers who are engaged in important weapons systems work being done by our Computer and Control Systems Laboratory. If you have a knowledge of modern airborne weapons systems, including the aspects of data collection, processing, and real time digital control functions, you may wish to work on new and very comprehensive Litton Industries programs.

Mechanization of logic wiring, predetermined in optimum form by computer simulation, is discussed by W. Ruppenthal and W. Reimann

LITTON INDUSTRIES Electronic Equipments Division
336 North Foothill Road, Beverly Hills, California

BULLETINS AND CATALOGS

(300) WIRES & CABLES. John A. Roebling's Sons Corp. Catalog J-923, 56 pp. Covers a complete line of rubber and thermoplastic insulated power and control cables. Photos, sketches, and tables in each subsection provide complete details on copper and aluminum conductors, various types of rubber and plastic insulations, nonmetallic and metallic sheathing materials, and recommended shielding practices.

(301) MAGNETIC AMPLIFIERS. Vickers, Inc. Bulletin E-PD-1296-5, 4 pp. Gives full specifications on the company's 1290 Series gapless-core magnetic amplifiers, which consists of 18 models with power outputs of from 500 va to over 32 kva.

(302) NUMERICAL CONTROL. Ampex Corp. "Readout", Vol. I, No. 2, 16 pp. Published by the Ampex Instrumentation Div., this bimonthly magazine contains a number of timely articles on the application of magnetic tape equipment. Of particular interest in this issue is a four-page article on the economics of a tape-controlled skin miller.

(303) PNEUMATIC CIRCUITS. Westinghouse Air Brake Co. Booklet, 24 pp. Entitled "Devices and Fundamentals of Air Circuitry", this well-illustrated brochure shows how pneumatic components can be used to perform the basic logic functions, describes the operation of various types of valves and positioners, and demonstrates applications such as station transfer control, automatic cycling, and safety interlocks.

(304) FLOW PICKUP. Ramapo Instrument Co. Brochure, 4 pp. Completely describes the Mark V Flow Transducer, a device designed specifically for measuring single or bidirectional flow. A section on general specifications covers such details as range, operating pressures and temperatures, frequency response, line sizes, and materials.

(305) SERVOMOTORS. Norden Div., United Aircraft Corp. Bulletin 385A, 10 pp. Contains application data for both standard and custom servomotors, including schematics for vacuum-tube, transistor, and magnetic-amplifier operation.

(306) CONTINUOUS ANALYSIS. Beckman/Scientific & Process Instruments Div. Bulletin CL-4000, 8 pp. Provides descriptive information on a complete line of process stream analyzers, including industrial pH equipment, gas chromatographs, infrared analyzers, and oxygen analyzers.

(307) PROCESS CONTROLS. B-I-F Industries, Inc. Bulletin No. 100-R5, 8 pp. Photos and sectional drawings illustrate descriptions of 12 products designed for the positive control of materials in motion. These include flowmeters, valves, positioners, supervisory controls, telemetering equipment, and some special-purpose devices.

(308) COMPACT ANNUNCIATOR. Panellit, Inc. Bulletin 103, 4 pp. Reviews the more important features of the completely integrated, space-saving Series 61

annunciator, a system for monitoring 24 to 96 points in the utility or continuous process industries.

(309) CONNECTOR TESTING. The Deutsch Co. Report, 29 pp. This detailed report covers the laboratory testing of the company's miniature electrical connectors. Tests of electrical, environmental, and physical characteristics are completely described, and the results tabulated.

(310) INFRARED ANALYSIS. Perkin-Elmer Corp. Brochure, 22 pp. Leads off with an interesting section describing infrared spectroscopy and where it is used. Main sections deal with the Model 137 Infracard Spectrophotometer, its optical system, its performance, and some typical applications.

(311) HIGH-VOLTAGE CONTROL. Cutler-Hammer, Inc. Publication EN-162, 16 pp. Discusses general features as well as individual characteristics of full- and reduced-voltage types of high-voltage control for squirrel-cage, synchronous, and wound-rotor motors.

(312) LOGIC MODULES. Hoffman Electronics Corp. "Semiconductor Application Notes", Vol. I, No. 7, 8 pp. Seventh in a series on semiconductor applications, this issue describes 12 typical uses for Hoffman's Magnalog logic modules, miniature semiconductor circuits mounted on a seven-pin plug-in base.

(313) MAGNETIC HEADS. Ampex Corp. "Readout", Vol. I, No. 1, 16 pp. Lead article in the first issue of this new company magazine describes the evolution that has taken place in the development of magnetic heads for tape equipment. Cites advantages of current designs.

(314) CABLED TUBING. Crescent Insulated Wire & Cable Co. Bulletin No. 458, 12 pp. Covers a complete line of Armored Multitube cables for pneumatic and hydraulic applications in power plants, refineries, chemical plants, paper mills, etc. Photos illustrate the variety of types available with from two to 37 tubes.

(315) RELAYS & CONTACTORS. The Rowan Controller Co. Type "B" Folder, 16 pp. Offers complete engineering data on two relays and six contactors with current ratings from 10 to 75 amp. Illustrations include photos, circuit diagrams, performance curves, and dimension drawings.

(316) MOTOR CONTROLS. The Arrow-Hart & Hegeman Electric Co. Condensed Catalog No. 14, 78 pp. Gives complete size, weight, and ratings information on a variety of motor control equipment. Products include manual starters, magnetic relays, magnetic contactors and starters, reversing contactors and starters, combination starters, pushbuttons and stations, and other controls and accessories.

(317) INTEGRATING RECORDER. Minneapolis-Honeywell Regulator Co. Specification S153-20, 4 pp. Provides a detailed description of Honeywell's ElectroniK strip chart recorder with continuous integration. A simulated chart record illustrates the action of the dual pipping pen that prints the record of peak integrations.

(318) SWITCHING TRANSISTORS. Sprague Electric Co. Enginering Data

Sheet 2N501, 4 pp. Describes the Type 2N501 micro-alloy diffused-base transistor for ultra-high-speed switching applications. Tables list maximum ratings, mechanical specifications, and electrical characteristics.

(319) THERMOMETER WIRE. Secon Metals Corp. Brochure. Written to aid in better resistance-thermometer design, this booklet illustrates the resistance vs. temperature characteristic of various pure metals and alloys. Also covers the different types of enamels best suited for different temperature ranges.

(320) POWER SUPPLIES. Lambda Electronics Corp. Catalog, 36 pp. Presents the company's full line of transistor- and tube-regulated power supplies. Photos show some typical applications.

(321) AIR & HYDRAULIC VALVES. Beckett-Harcum Co. Bulletin, 8 pp. Discusses the design features of the company's HiCyclic line of air and hydraulic control valves, and tabulates operating characteristics and dimensions.

(322) TEMPERATURE CONTROLS. Partlow Corp. Folder, 4 pp. Introduces the Model RVA recording pneumatic temperature control, and the Model IVA indicating control. Table shows the temperature ranges available.

(323) PUSHBUTTON ACTUATORS. Micro Switch Div. of Minneapolis-Honeywell Regulator Co. Data Sheet 155, 2 pp. Shows two new pushbutton actuators designed for a wide variety of basic switch types. Photos illustrate mounting dimensions while a table covers selection of switch types for different purposes.

(324) HYDRAULIC CYLINDERS. Hanna Engineering Works. Catalog 900, 8 pp. Large cutaway view of a typical cylinder illustrates important design features. Tables provide mounting dimensions and cylinder capacities. Bulletin also contains a handy model selection chart.

(325) THERMOWELL MATERIALS. Thermo Electric Co., Inc. Chart, 4 pp. Designed as a guide for thermowell users, this chart simplifies the selection of proper thermowell materials for different applications. Four column heads are Industry, Application, Conditions, and Well Material.

(326) CONTROL MOTOR. Rotron Controls Corp. Bulletin CM-13, 1 page. Photo, dimension drawing, and a list of specifications are used to illustrate the more important features of a new 1/6-hp industrial dc control motor.

(327) CONTROL PANELS. General Electric Co. Bulletin GEA-6701, 4 pp. Discusses control panels and operator control stations for use in metal rolling and processing industries. Line drawings show dimensions for different NEMA classes; photos illustrate six typical applications.

(328) MOTION INDICATOR. The Bin-Dictator Co. Form 3547, 4 pp. Describes the construction, installation, and operation of the Roto-Guard motion indicator, a device for converting various types of motion into an electric signal.

(329) SENSITIVE PHOTOMETER. American Instrument Co. Bulletin 2295. Offers complete information on a new

absolute light-scattering photometer that permits studies of high-molecular-weight compounds, determination of particle sizes in the submicron ranges, and the recording of haze and turbidity in moving streams.

(330) MERCURY SWITCHES. Gordos Corp. Catalog, 8 pp. Tables list physical and electrical characteristics of a complete line of mercury switches designed for various types of switching action at various differential angles. Model numbers of equivalent Micro Switch and General Electric types are included for convenience.

(331) DATA LOGGERS. Monroe Calculating Machine Co., Inc. Brochure, 4 pp. Deals with the Series MC-203 Data/Log, an electrically-actuated printing machine that permits simultaneous entry of up to 14 digits and has an automatically-indexed carriage that will handle paper widths to 18 in.

(332) ELECTRONIC TIMER TEST. Rectifier-Capacitor Div., Fansteel Metallurgical Corp. ReCap, Vol. 2, No. 5, 4 pp. Lead item describes a million-cycle test of a Wheaton electronic time delay relay that uses a Fansteel tantalum capacitor in its timing stage. Also discussed is a servomotor drive for an airborne antenna.

(333) AN INFRARED ACCESSORY. Perkin-Elmer Corp. Data Sheet IR-AC-008-58, 2 pp. Tells how a new infrared instrument accessory, the Dual Long Path Cell, can be used for air pollution studies and in the quantitative analysis of hydrocarbon mixtures

(334) GAS ANALYZER. Mine Safety Appliance Co. Bulletin No. 0716-2, 4 pp. Explains the principle of operation and the advantages of the M-S-A Thermatron, a newly improved process control instrument for continuous measurement of the concentration of one gas in multicomponent mixtures.

(335) STANDARD DEFINED. American Standards Association. New brochure explains the nature of standards and describes the function of the ASA as the national clearinghouse for standardization in the United States and as the representative of American interests in international standards work.

(336) DIGITAL VOLTMETER. KinTel Div., Cohu Electronics, Inc. Data Sheet 19-27, 2 pp. Contains a quick review of the physical and electrical specifications of the Model 501 DC Digital Voltmeter System. Components include the control unit, six-window readout, probe, and interconnecting cable.

(337) SYSTEMS FACILITIES. Mechanical Div., General Mills. 24-page booklet. Delineates the functions of three departments within this division, Research, Engineering, and Manufacturing, and shows how their combined efforts provide a unified facility for military and industrial systems production.

(338) LEVEL GAGES. Jerguson Gage & Valve Co. Bulletin No. 338-10/58, 8 pp. Provides detailed coverage of a complete line of remote-reading liquid-level gages for commercial and industrial applications. Well-illustrated sections deal with operation and application.

WHAT'S NEW

(Continued from page 60)

well-known to each other, and all take part in the preparation and presentation of proposals.

• **Workable and reliable**—The system has proved very flexible—though, by Hoffman's own admission, there has been only one contract, Tall Tom, to go on. Still, Hoffman points out that subcontract and contract changes have been issued promptly, supports this by declaring that the preproduction prototype specifications—phase one of Tall Tom—were delivered to the Air Force right on schedule, and promptly approved. (The firm would not say whether or not it is now directing its eight subcontractors in the construction of a prototype system.)

In keeping with its reluctance to say very much about TEAM, Hoffman would not reveal any cost or profit figures on its one TEAM contract, nor give any indication of how business has fared as a result of the use of the concept. Nor, despite the fact that it has only praise for TEAM, would it explain why it did not see fit to apply the approach to its bigger-than-Tall Tom contract, a $33 million TACAN air navigation equipment job for the Air Materiel Command.

Hoffman is very vocal about this new contract, which calls for the hiring of several hundred additional production and technical personnel. TACAN (tactical air navigation) is a short-range (200-mile) radio aid that gives a pilot continuous information about direction and distance from a ground station. A past major supplier of the airborne portion, Hoffman has been asked to improve its contribution and in addition develop new types of TACAN equipment for use with advanced weapons.

• **A pulse transmitter**—The airborne part of TACAN is a small, compact set about 8½ by 11 by 17 in. and weighing about 60 lb. It is actually a transmitter and receiver, giving out pulses to interrogate a ground station. Information is displayed on two indicators, one for distance and the other for bearing.

The Laboratories Div. has overall responsibility for TACAN.

IT&T Corp. Consolidates Federal T&R, Farnsworth

International Telephone & Telegraph Corp. has consolidated two divisions, Federal Telephone & Radio Co. of Clifton, N. J., and Farnsworth

WHAT'S NEW

Electronics Co. of Fort Wayne, Ind. Delbert L. Mills, president of Federal, will head up a new single management at Clifton, and Vernon L. Haag, vice-president of the Farnsworth missile test equipment section, will be general manager of operations at Fort Wayne.

Eastern Precision Resistor Buys Epsco, Digitronics Lines

Last Jan. 12, Epsco, Inc., and Digitronics Corp., an Epsco property, announced they had sold their delay line business to Eastern Precision Resistor Corp. of Brooklyn, N. Y. The move accomplished three things: it permitted Epsco's Components Div. to direct more of its energy toward the digital field; it gave Digitronics room to expand its commercial data-handling business; and it provided Eastern Precision with the means to diversify and enlarge the scope of its operations, which are principally concerned with wire-wound precision resistors and resistor assemblies.

Epsco's pulse transformer business also went to Eastern Precision. Together, these lines represented about 5 percent of Epsco's business. Their sale came shortly after the Components Div.'s introduction of a new line of low-cost, encapsulated, transistorized digital plug-in circuits to be used as building blocks for equipment and system manufacture. This is the line that prompted Epsco's deck-clearing.

Digitronics also sold another line, its Magnetic Tape Transport Div., to Fairchild Camera & Instrument Corp. In Digitronics' case, too, the lost business represented a small part of its operations.

Consolidated Controls Get Subcontract for A-Destroyer

Consolidated Controls Corp., one of the Danbury, Conn., group of control companies (CtE, Jan., p. 46), has received AEC and General Electric contracts totaling about $600,000 for the design and manufacture of primary plant instrumentation for the first nuclear powered Navy destroyer. Coming almost on the heels of a Westinghouse assignment for reactor controls for similarly powered submarines, the award puts Consolidated definitely in the vanguard of companies active in nuclear development.

The propulsion system for the destroyer and its land prototype are being designed by the AEC's Knolls

Atomic Power Laboratory at Schenectady, N. Y., operated by GE.

Besides following through on the $800,000 Westinghouse project and the AEC-GE one just received, Consolidated is also at work on the instrumentation for a nuclear-powered aircraft carrier.

Convair Instruments Raises Status of Missile Parts

In San Diego, Calif., instruments developed for Convair's gigantic missile and aircraft projects are receiving recognition as more than simply weapons-systems components. An organization called Convair Instruments is handling these by-products, refining them into products in their own right, and marketing them. This means that "for the first time," in the words of J. V. Naish, president, "Convair has an organization to exploit the instrument by-products that are a natural outgrowth of our primary work on advanced missile and aircraft systems."

In many respects, the new group, which started out as Datafax Instruments in La Jolla, Calif., a few months ago, parallels the parent firm's Hyge Machines works at Pomona, Calif., manufacturer of shock simulation and dynamic loading machines, and such general-purpose equipment as rapid-acting valves and actuators, and high-velocity, high-energy machine tools for sheet metal-working, forging, extruding and impacting.

The new group conducts its own development work in addition to doing weapons-product exploitation, and concentrates activities around three broad instrument categories: mechanical, ac- and dc-current measuring devices, and transducers to handle pressure and time. Two interesting entries in these categories: a liquid gas detector, and a dc voltmeter capable of measuring voltages ranging from a microvolt to 1,000 volts over nine ranges.

The liquid gas detector, a small electronic probe, inserts in a liquid oxygen, helium, hydrogen, or other cryogenic materials pipeline, and determines whether the material in the line is in a liquid or gaseous state. It works by measuring resistance change in a very fine heated wire, which responds more readily to liquid than to gas or vapor.

The dc voltmeter, completely transistorized, employs printed circuitry throughout. It is the first in a new line of current measuring instruments.

WHAT'S NEW

IMPORTANT MOVES BY KEY PEOPLE

John W. Carr Heads N. C. Computation Center

John W. Carr III, a CONTROL ENGINEERING author (Jan., Feb., and March, 1956), has been appointed director of the new Computation Center at the University of North Carolina, and associate professor of mathematics there. Carr had been associate professor of math at the University of Michigan. He is a former president of the Association for Computing Machinery.

Heart of the new computation center is a Univac Scientific ERA-1105 digital computer. It will be located on the Chapel Hill campus, but will be available to all students of the consolidated university; i.e., those at Chapel Hill, at North Carolina State College of Agriculture & Engineering at Raleigh, and at the Women's College at Greensboro.

Ling Electronics, Calidyne Merger Spurs Appointments

Several top-level appointments have been made in the wake of the Ling Electronics-Calidyne Co. merger (CtE, Nov. '58, p. 40). Part of a program of accelerating engineering and manufacturing operations and broadening sales-service facilities of new Ling vibration systems, the appointments include:

James A. Ross, a Ling vice-president, to chief engineer of R&D with overall responsibility for engineering policy at both the Culver City (Calif.) and Winchester (Mass.) plants; Charles Theodore, vice-president in charge of sales, to supervisor of Ling sales-service groups in the east and the west; and Stanley H. Walters, formerly with Calidyne, to eastern regional sales manager. Ralph B. Austrian continues as western regional sales manager.

Top-Level Changes Follow General Precision Restructure

Also generating new appointments is the recent change in corporate structure at General Precision Equipment Corp. (CtE, Oct. '58, p. 46). Top subsidiary officers are:

D. W. Smith, president of Kearfott, Inc., named group vice-president in charge of three subsidiaries, General

Precision Laboratory, Inc., Librascope, Inc., and his own Kearfott; D. D. Mason, president of Link Aviation, Inc., named group vice-president in charge of GPE Controls, Inc., Shand & Jurs Co., and Link; J. W. Murray, president of GPL, and L. W. Imm, president of Librascope, named vice-presidents of the parent company; and R. N. Harder, formerly vice-president and treasurer of GPEC, named first vice-president and treasurer.

Cmdr. Hoover Leavers ONR, Goes to Benson-Lehner

George W. Hoover, formerly manager of aircraft systems in the Air Branch of the Office of Naval Research, has joined Benson-Lehner Corp. as director of technical planning. It was rumored that once having made his intention to leave ONR known, Hoover received more than 30 offers of space-research positions from major U. S. firms. His most recent project at ONR involved an Army-Navy instrumentation program aimed at achieving a design for an "integrated cockpit", i.e., one in which all controls used by the pilot are literally at his fingertips and the motions he makes are natural and comfortable. Hoover's interest in, and contributions to space travel were fully explored in a *Personality* sketch about a year ago (CtE, April '58, p. 17).

W. A. Liebermann Named Chief Engineer of Metrolog

Metrolog Corp. of Pasadena, Calif., the electronic instrumentation and component subsidiary of Air Logistics Corp., has appointed Walter A. Liebermann chief engineer. Berlin-educated Liebermann formerly was head of electronic power-supply development at Northam Electronics, Inc. Before that he was engaged in electronic research in Argentina.

Other Important Moves

Bell Telephone Laboratories has elected **James B. Fisk** president, succeeding **Mervin J. Kelly**, who becomes chairman of the board. Fisk's successor as executive vice-president, a post he held since 1955, is **Estill I. Green**, formerly vice-president for systems engineering. Fisk joined Bell Labs in 1939, after doing distinguished work in education and industry, both in this country and in England. His long service with Bell has been punctuated by appointments to Harvard as Gordon McKay professor of physics, and to the AEC as director of the Div.

WHAT'S NEW

of Research. Kelly, who came to the laboratories in 1918, was appointed director of research in 1936, executive vice-president in 1944, and president in 1951. Green was named to his most recent position with Bell Labs in 1955. All three men are fellows of the IRE and are active in other professional societies, too.

Edward Hoffart, formerly chief engineer of Topp Industries, Inc., has been appointed an executive staff engineer at Hoffman Electronics Corp.'s Laboratories Div.

H. J. Wissemann, assistant vice-president of Texas Instruments' Apparatus Div., and before that the division's chief engineer in charge of design and development, is now its general manager. He joined TI in 1945.

Tuthill Pump Co.'s new chief engineer is **Ernest H. Schanzlin.** He comes to the Chicago firm from the Pesco Products Div. of Borg Warner Corp., where he was assistant to the director of engineering. He had also been chief engineer of Pesco's Engineering Dept.

Ronald Bell has joined Greer Hydraulics, Inc., as senior research physicist. His area will be servo systems, transistorized circuitry, etc. He comes to the Jamaica, N. Y., company from the Bell System's Westrex Div.

Obituaries

Hans R. Friedrich, assistant chief engineer for development at Convair-Astronautics. He had been hospitalized since suffering a heart attack in November. Friedrich was the subject of a *Personality* sketch about a year and a half ago (CtE, Nov. '57, p. 19).

Alexander M. MacLennan, 64, who recently retired as assistant vice-president for public relations of IT&T; of a heart attack at Del Ray Beach, Fla.

Alfred A. Markson, 54, assistant vice-president of Hagan Chemicals & Controls, Inc.; at his home in Pittsburgh, Pa.

Charles B. McBride, president and chairman of the board of The Thermix Corp., Greenwich, Conn., developer of aircraft instruments and controls; of a heart attack in Amagansett, N. Y.

Charles S. Redding, 75, chairman of the board and former president of Leeds & Northrup Co.

John P. Toner, 46, assistant chief engineer in the Arma Div. of American Bosch Arma Corp., and head of the division's Research Dept.; at his home in Halesite, N. Y.

ABSTRACTS

Like an Economics Problem

From "The Optimum Control of Multi-Actuator Systems" by Ian McCausland, University of Toronto, Ontario, Canada. AIEE Transactions Paper No. 59-198, presented at the AIEE Winter General Meeting, New York, N. Y., Feb. 1-6, 1959.

The problem of controlling a multi-actuator system is somewhat analogous to a problem in economics of maximizing the "utility" derived from the purchase of several commodities.

Take the simple case of two commodities, x and y. To the consumer, the utility of each is a function of the amount purchased, and drops off faster beyond a certain amount. Curves for both these functions can be drawn on a three-dimensional plot, as in Figure 1. These curves form boundaries for

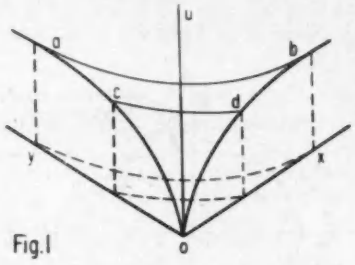


Fig.1

a three-dimensional "utility surface". The height of any point on this surface represents the total utility contributed by both x and y. Lines such as *ab* and *cd* on the utility surface represent lines of constant utility and are called indifference curves. Vertical projections of these curves can be plotted directly on the xy plane from the known relationship

$$\frac{dy}{dx} = \frac{\partial u/\partial x}{\partial u/\partial y}$$

These projected indifference curves can then be used to determine the maximum utility of a particular expenditure. Figure 2 illustrates several

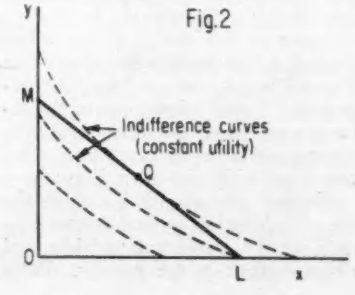


Fig.2

ABSTRACTS

indifference curves in the xy plane. The line *LM* shows how much x and y can be purchased with a particular fixed expenditure. At some point, such as *Q*, this line is tangent to one of the indifference curves. This point represents maximum utility, since any other point on the line is on a curve of lower utility.

A two-actuator control problem can be handled in much the same way. Instead of commodities, however, x and y now represent inputs or effort required of each actuator to produce a desired output. Also, the concept of "penalty" replaces that of "utility"; i.e., as effort increases, the "penalty" or cost of this effort also increases. Unlike the utility-vs.-commodity curves, however, the penalty-vs.-effort curves have an increasing rather than decreasing incremental change as they get further from the origin. Indifference curves of penalty then are concave to the origin, as shown in Figure 3. Since effort input can be in either

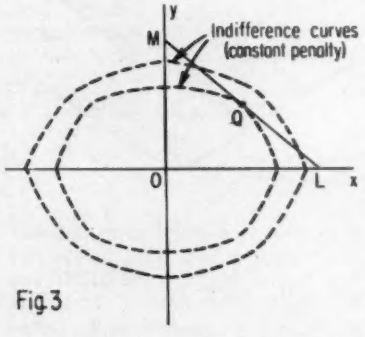


Fig. 3

direction these curves can be plotted in all four quadrants.

Output or total effort delivered is like the available expenditure in the economics problem above. All can be derived from either input or some from each. The line *LM* again shows the possible combinations of inputs x and y. In this case, too, point *Q* represents the most desirable combination, for here the line is tangent to a minimum penalty indifference curve. At any other point, line *LM* intersects a line of higher penalty.

Applying this theory to an actual control system requires the assumption that all inputs are at very low frequency. Transfer functions of the actuators are based on steady-state conditions and are determined by varying one input while the other is at zero.

Physical realization also requires the use of a function generator whose inputs are the significant variables and whose output is the penalty. With

this information, the controller can seek a point of minimum penalty by making necessary changes in the variables or actuator inputs.

Single-variable regulators and two-input-two-output regulators can also be designed to take advantage of this technique.

One of the more interesting applications, and one in which power economy is a most important consideration, would be a five-stand tandem cold-rolling mill for steel strip. If, in this case, thickness is controlled by adjusting roll separation of stand 1 and torque of the motor at stand 5, and, at the same time, the tension of the strip between stands 4 and 5 is held within limits, the penalty function used must depend on these variables plus the desired output thickness. The controller for such a system could be developed for the most part from suitable analog computer components. Digital equipment and sample-data techniques could also be used. These would compute penalty function values at selected points in the region of operation and make logical decisions as to the best course.

Temperature Measurement

From "A Cooled-Gas Pyrometer for Use in High-Temperature Gas Streams" by L. N. Krause, R. C. Johnson, and G. E. Glawe, all of the Lewis Research Center, Cleveland, Ohio. Technical Note 4383 of the National Advisory Committee for Aeronautics (now National Aeronautics & Space Administration), Washington, D. C., September, 1958.

Selection of thermocouples for measuring temperature in high-velocity gas streams often demands a compromise between accuracy and structural considerations. At higher temperatures the difficulties become even more pronounced, often exceeding the limits of thermocouple design.

Two of the more recent developments in this area are the pneumatic probe and the cooled-tube pyrometer. A third instrument, and the subject of this paper, is the cooled-gas pyrometer. This device involves the controlled cooling of the gas before taking a temperature measurement with a thermocouple. Drawing the hot gas through a tube with cooled walls provides this controlled cooling. Loss in energy of gas is reflected by a drop in gas temperature. This temperature drop depends on: flow within the tube, gas properties, tube geometry, and tube wall temperature. If the temperature

ABSTRACTS

drop can be calculated and the temperature of the cooled gas measured, total temperature of the free-stream gas can be determined.

Physically, the new pyrometer consists of three concentric tubes, the largest tube having an outside diameter of ½ in. Hot gases pass through a ¼-in. tube in the center. Inlet water flows in the inner annulus and in opposite direction to the gas flow. Outlet water is parallel to the gas flow.

Pneumatic Computing

From "Universal Pneumatic Multiplication-Division Unit and a Device for Automatic Square-Rooting" by Yu I. Ivlichev and E. M. Nadzharoz. An article in the Soviet journal Avtomatika i Telemekhanika, Vol. 19, No. 11, 1958, pp. 997-1009. Translated and abstracted by Peter N. Budzilovich of McGraw-Hill's Technical Writing Service.

This paper describes and analyzes the performance of two pneumatic devices developed at the Pneumo-Hydro-Automatics Laboratory of the Institute of Automatics & Telemechanics at the Academy of Science in the U.S.S.R.

The first of these, a pneumatic multiplying-dividing unit, provides an output equal to the product of two variables divided by a third. This can be expressed in the form of a simple equation: $p_4 = p_1 p_2/p_3$, where p_4 is the output pressure and p_1 p_2 and p_3 are input pressures. All are expressed in pounds per square inch gage and can range in value from 0 to 1 atmosphere.

If certain of the input pressures remain constant, a variety of operations can be performed. These include: multiplying, dividing, inverting, squaring, combining some of these, and wide-range amplification of one input.

Following a qualitative description of the unit, the authors review its static characteristics, possible errors in its static analysis, and discuss its dynamic performance.

The square-rooting device consists basically of the same multiplying-dividing unit, with feedback added to insure that p_4 equals p_3. The equation above then becomes $p_4^2 = p_1 p_2$ or $p_4 = p_1 p_2$.

In analyzing the performance of this unit, the authors follow the same procedure as above; i.e., provide a qualitative description and review its static and dynamic characteristics. Graphs and tables illustrate their experimental results.

—Peter N. Budzilovich

NEW BOOKS

Control Applications Stressed

ORDINARY DIFFERENTIAL EQUATIONS. *Wilfred Kaplan, Dept. of Mathematics, University of Michigan. 534 pp. Published by Addison-Wesley Publishing Co., Inc., Reading, Mass. $8.50.*

Essentially a text for an undergraduate course in differential equations, this book definitely has been written with the interests of the would-be control engineer in mind. And recognizing its emphasis, the publishers have made the book part of their new series in systems engineering.

The author rigorously covers all the topics usually included in an introductory course. To illustrate the theory and provide a better understanding of mathematics as a tool, he relates the equations to their applications in physics and engineering, putting particular emphasis on applications in the field of systems analysis.

Here is an excellent starting point for studying the more advanced books on feedback control systems.

Emphasis on Systems

DYNAMIC BEHAVIOR OF THE PRODUCTION PROCESS . . . PROCESS DYNAMICS. *Donald P. Campbell, late consulting engineer. 316 pp. John Wiley & Sons, Inc., New York, 1958. $10.50.*

For the first time in a book, a systematic attempt has been made to define dynamically certain of the process operations. For the most part, these operations are of interest to the chemical process engineer. The chapter titles are enough to whet the curiosity: kinematics of material handling; fluids in motion; forming, propulsion, and guidance; thermal process dynamics; mass transfer dynamics; and chemical process dynamics.

Unfortunately, the curiosity may not be satisfied in the reading. Although many things make the work unique and valuable, one of them is not that process engineers will be aided directly by use of the book's contents. Dynamic analysis is formidable; so much so, that the cases considered are of rather ideal nature. Process design, by empirical and semitheoretical methods, has advanced plant equipment far beyond the rudiments used here.

Nonetheless, the book is a noteworthy forward step in showing engineers that optimum plant design is not just a question of hooking together so many unit operations with so many

NEW BOOKS

feet of pipe. It is a strong signal of an outlook that may become increasingly significant as companies look for tighter design to help them remain economically competitive in the fast-moving chemical process industries.

The book, then, will perhaps find shelf space, but in the library of the control engineer rather than the process engineer. The processing problems are familiar and basic, but the analytic technique is sophisticated. The reader should be facile with the mathematical tools of partial differential equations and the Laplace transformation. He should at least have had time to study the author's earlier book on feedback control (*Principles of Servomechanisms*, co-authored by G. S. Brown). A knowledge of the nature of processing problems is not required because such explanation, when needed, has been included. (Two brief appendices jog memories on the use of block and signal flow diagrams and the Laplace transformation.)

Typical of the treatment, the unit operation of continuous binary distillation is found in the chapter on mass transfer dynamics. In this section, the reader is oriented to the problem by means of a nonmathematical explanation of what happens during distillation in a hypothetical column. The text considers material movement, hydrodynamics, and heat transfer. The orientation is followed by the theory of distillation material separation, including an explanation of the McCabe-Thiele diagram. This latter design tool readily lends itself to transition to a single plate dynamic study. Differential material-balance equations are written and linearized to find time constants. Block and signal flow diagrams for a plate are then constructed, as are signal flow diagrams for several complete columns. A summary warns the reader that many barriers block solution of more complicated cases, cites some of them specifically—e.g., computational problems.

Campbell (who died in 1957) contributed most, in this work, to the concept of a quantitative process physics for the *entire* plant that may make possible better performance at lower investment. By selecting particular operations and defining the dynamic problems—first qualitatively, then empirically and theoretically, and finally analytically—he threw a searchlight on a vast frontier of new design techniques. One does not turn from the book feeling that all is solved, but rather that much fruitful advance may be based upon these first probes.

MEETINGS

MARCH

Western Joint Computer Conference, Theme: New Horizons with Computer Technology, Fairmont Hotel, San Francisco March 3-5

Instrument Society of America, Ninth Annual Iron & Steel Conference, Theme: Instrumentation in the Iron and Steel Industry, Pittsburgh March 11-12

American Institute of Chemical Engineers, National Meeting, Session on Computing Control (March 17), Chalfonte-Haddon Hall Hotel, Atlantic City March 16-18

Institute of Radio Engineers, 1959 National Convention and Exposition, Waldorf-Astoria Hotel and New York Coliseum, New York March 23-26

American Society of Mechanical Engineers, IRD Conference, sponsored by AIEE, IRE, ISA, and AIChE, Case Institute, Cleveland March 29-April 2

21st American Power Conference, sponsored by Illinois Tech, Hotel Sherman, Chicago March 31-April 2

APRIL

International Atomic Exposition and Nuclear Congress, Public Auditorium, Cleveland April 5-10

Instrument Society of America, Second National Symposium on Chemical and Petroleum Instrumentation, St. Louis April 6-7

American Institute of Mining & Metallurgical Engineers, 42nd National Open Hearth Steel Conference and Blast Furnace, Coke Ovens and Raw Materials Conference, Jefferson Hotel, St. Louis April 6-8

American Society of Mechanical Engineers, Hydraulic Div. Conference, University of Michigan, Ann Arbor April 13-15

Conference on Industrial Instrumentation & Control, sponsored by Armour Research Foundation, Illinois Tech campus April 14-15

Instrument Society of America, Oak Ridge Section, Fifth Annual Southeastern Regional ISA Conference and Exhibit, Gatlinburg, Tenn. April 20-22

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The following reprints have been prepared to make important reference-type editorial material available to CONTROL ENGINEERING readers in convenient filable form. Some reprints are individual articles, while others are "packages"—several articles published over a period of time that logically supplement one another in the coverage of a specific phase of the control field. Any reprint can be obtained at the nominal cost listed below by filling in the order form and sending it, together with remittance, to Readers Service Dept. Quantity rates will be quoted on request.

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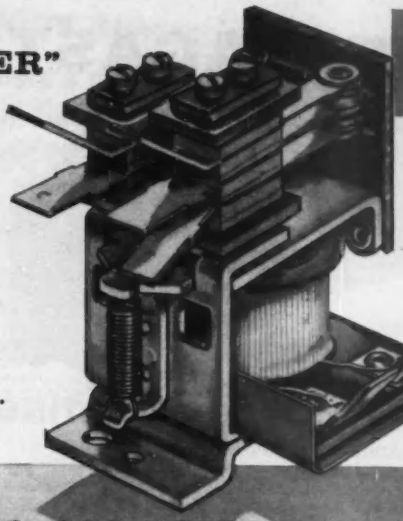

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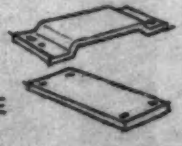

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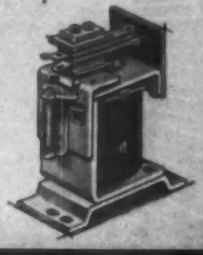

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Continued on Page 195

REPRINTS cont'd

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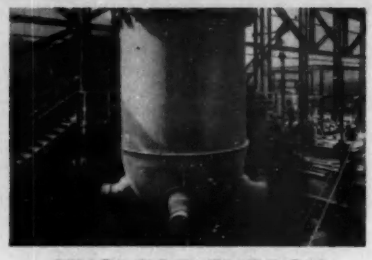

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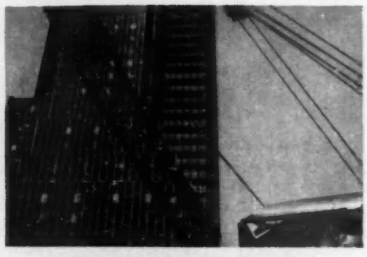

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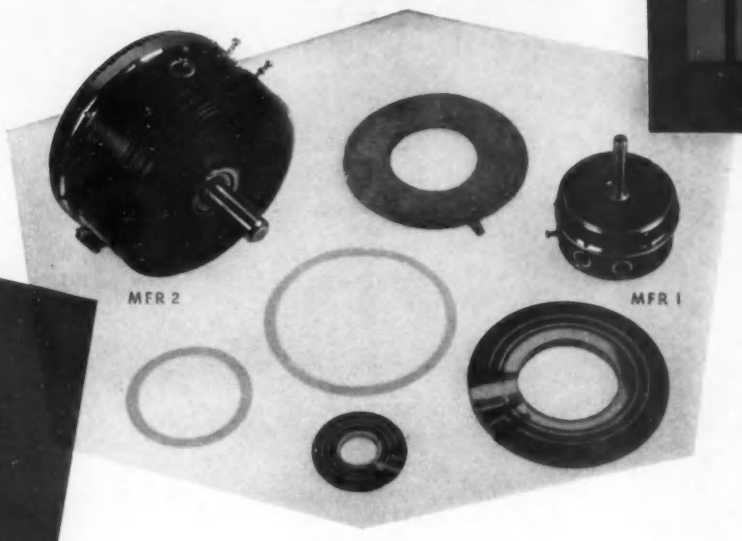

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MY HOUSEMAID'S ELBOW

IS GONE . . . GONE . . . GONE

My title was "Process Operator." Really I was just a cleaning lady for a roomful of blocked-up flowmeters. Took half my time taking them apart and putting them together again and the other half cleaning them out. I tried *everything* . . . bottle brushes, live steam, chinese backscratchers, aqua regia. The last straw was the plumbers' helper my wife gave me for my birthday.

I was all set to turn in my wrenches and plunger when a new kind of meter came in from Fischer & Porter. They call it a Magnetic Flowmeter. I stuck my hand in to see what new obstruction they'd dreamed up for me. But my hand went clean through and out the other end! I couldn't believe it.

NOW I believe it all right. Everything is changed. No more bottle brushes . . . no wrenches . . . no plumbers' helper. Nothing but a lot of grey boxes. NOW I know all about F&P Magnetic Flowmeters. And I can tell you that if *you're* tired of breaking lines to clean out meters, *you can throw your apron away!* Get the facts on a man's flowmeter. Write for Catalog 10D1416, Fischer & Porter Company, 739 County Line Road, Hatboro, Pa. In Canada, write Fischer & Porter (Canada) Ltd., 2700 Jane Street, Toronto, Ontario.

FP

FISCHER & PORTER CO.

Complete Process Instrumentation

CIRCLE 3 ON READER-SERVICE CARD